秘書處專用
申請編號：SFDF-0016

漁業持續發展基金
期終報告書

請填妥這份期終報告書，並於項目完成後的四個月內送交漁業持續發展基金秘書處。請注意，這份報告書將會上載至漁護署網頁供公眾查閱。

項目名稱：魚排上建立示範及教育單位，展示商業上可行的循環海水育苗系統(Ref.:SFDF-0016)

申請機構：香港城市大學海洋污染國家重點實驗室

批准日期：2017年4月1日

資助款額：港元3,778,880

報告期間：2021年4月1日 至 2021年9月30日

注意

凡故意在本報告書中作失實陳述或漏報資料，有關項目可被中止發放資助款項，而受資助者被發現有虛報資料，亦可遭檢控。受資助者須注意，以欺詐手段取得金錢利益，屬刑事罪行。

聲明

本人證實所夾附的期終報告書和經審計帳目，以及所提交的額外資料和證明文件均正確無誤，所購買的物料（包括資產）和獲取的服務，是本項目內的活動所必要的，而且價格公道合理。

[redacted]

簽署並機構蓋印

機構負責人姓名：[redacted]

香港身分證號碼：--

日期：2022年1月31日

修改版本日期：2022年10月26日

1. 項目時間表

開始日期		完成日期	
原定（*根據協議所示*）	實際	原定（*根據協議所示*）	實際
2017 年 4 月 1 日	2017 年 4 月 1 日	2020 年 3 月 31 日	2021 年 9 月 30 日

2. 項目目的撮要

- ➔ 優化魚苗育成，利用循環水過濾系統改善魚苗的生存環境質素及提高幼魚的存活率
- ➔ 為養殖戶示範魚苗育成系統的結構及製作運作手冊，與業界分享優化魚苗培育經驗

香港城市大學海洋污染國家重點實驗室 (SKLMP) 聯合香港本地水產養殖專家及獸醫，共同研發適合本地環境的水產養殖科技，同時配合本土養殖業的豐富經驗，藉以協助業界解決目前本港養殖業最大難題之一：提高魚苗和幼魚的存活率。

2.1 優質魚苗的重要性

根據本港養殖業經驗，魚苗質素和存活率是整個養殖周期中最主要的成功關鍵因素之一。目前香港的魚苗主要從外地進口，例如中國大陸、印尼、馬來西亞及台灣等地。養殖戶進口魚苗 時，若選擇早期較小的魚苗，價錢及運輸成本相對較低，而且投放密度較高，但是卻面臨存活率低的極大投資風險，而養殖戶若選擇晚期較大的魚苗，魚群抗病力高，耐寒且養殖時間短，可儘快獲利，但是最大的困難是價錢及運輸成本相對提高且運輸量低，增加了整體養殖成本。為了要解決這兩難的情況，其中一種方法是將進口的早期較小魚苗，先以密閉式循環水過濾系統將魚苗小心地培育成較大的幼魚，才進行開放式海水網箱放養。這方法可以有效阻隔紅潮及寄生蟲的侵害，大大提高幼魚的存活率。

上述方式看似簡單，但其技術、設備與操作知識卻相對有較高要求，然而由於普遍養殖戶不僅缺乏相關的技術訓練與標準養殖操作指引，更無法得知其長期商業成效，所以業界極需一套有系統的養殖示範及專業培訓，了解新式養殖方法的可靠性並確保認識投資的風險與回報，藉此提升本港養殖業技術。

2.2 優化魚苗育成方案

2.2.1 示範魚種及來源

石斑魚是亞太地區最具經濟價值的養殖魚種。石斑魚由於成長快速、廣鹽性、適應本地養殖水溫，且易於管理加上市場售價高，所以一直深受香港養殖戶垂青。目前香港多由中國大陸、東南亞及台灣等地進口石斑魚魚苗，常見品種為青斑、芝麻斑、花尾龍躉與沙巴龍躉等。 本項目亦選擇本地漁民所熟悉的魚苗來源，這樣不但不會增加漁民的經濟壓力以及養殖技術難度，同時亦有利於明確地比較出不同養殖方式的成效。

2.2.2 中間育成方案

魚苗是養殖過程中死亡率最高的階段，魚苗的育成是石斑魚養殖技術的關鍵。本項目以優質石斑魚種(例如: 花尾龍躉)魚苗開展中間育成，包括利用循環水過濾系統改善魚苗的生存環境質素，紀錄及歸納工作程序，目標是提高幼魚的存活率，從約 2.5 吋魚苗(~6cm) 經優化中間育成至約 5 吋幼魚(~12cm)。短期不僅可為附近養殖戶提供養殖風險小，利潤高的大魚苗或幼魚，長期也可推廣養殖戶自己進行魚苗的中間育成並提升行業的可持續發展。

2.2.3 向業界示範及推廣

本項目最終目的是與業界分享本項目的項目循環水過濾系統及優化魚苗培育經驗。

項目循環水過濾系統的優點:

- 良好水質：有水質監控，較穩定；
- 容易監察魚苗狀態/食慾，有異常情況可以立即應對，如隔離治病，減低大量感染風險；
- 有效阻隔細菌/寄生蟲/紅潮傷害；
- 減少染病，減少使用藥物(如抗生素)，容易監察餵飼量，減少/回收有機廢物，有助改善養魚區自然生態環境，持續發展；
- 增加魚苗/幼魚存活率。

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3. 項目目的和／或範圍的更改 *（如有，請註明有何更改以及所持理由）*

項目目的或範圍沒有更改。

項目目的如下:

(1) 優化魚苗育成;

(2) 為養殖戶示範魚苗育成系統的結構及製作運作手冊;

(3) 增值研究(由 CityU SKLMP 提供資金)。

a. 魚病防控及疫苗研究；b. 生態養殖

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4. 報告期間的項目推行撮要

（請簡述主要活動，並按適當情況列明日期、地點及受惠人數）

項目原本預計 2022 年上旬的推行活動，因疫情關係延期，見**附件(1)**。

剩餘的花尾龍躉幼魚已於 2021 年 09 月 30 日售出，全部同屬於 2020 年 8 月進口的第 1 批花尾龍躉幼魚，共售出 180 尾，每尾$70 (每尾約 25cm，800-1000g)，收入共$12,600 元正。

報告期間，曾與秘書處開會討論申請提早處理受火警損壞的育苗器。由於沒有適合買家，未能轉售，實驗室已按程序尋找供應商棄置育苗器，詳見**第 9 項**。

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5. 參加者估計數目與實際數目的比較

日期	地點	活動	預計受惠人數	實際受惠人數	漁業界受惠人數
2021年5月13日	香港漁民團體聯會	業界工作坊	15 (受疫情影響，由50人減至15人)	12	12
2021年5月27日	香港漁民團體聯會	業界工作坊	15 (受疫情影響，由50人減至15人)	12	12
2022年7月29日	網上會議	業界工作坊	200人	70-80	50-60
其他擬議活動，見**附件(1)**，**表 2.2**。					

6. 項目的成效評估（根據申請計劃的成效指標）

詳見**附件(2)**。

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7. 項目延期（與原定時間表比較，並須交待原因）

由於採購及建設魚排設施需時比預定時間長，其間亦遇到一些困難（見第一、二、三及四次進度／年度報告書第6點）導致項目延期。與原定時間表比較，約延遲了18個月。

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8. 在報告期間所遇的問題（如有）

(1) 由於2021年2月26日，項目魚排發生火警事故，育苗器有三分之一已嚴重燒毀，有結構安全問題，結構重組前不能再運作(見第四次進年度報告書第6點)。由於育苗器已嚴重燒毀，未能於2021年再養殖第3批魚苗。我們於3月初向秘書處表示，基於時間及資金有限，預計未能於項目完結前完成育苗器的維修工作，以致項目未能達到部分成效指標，詳見**附件(2)**。

(2) 未能達到預期收支平行。

- 由於2017至2018年間因受颱風影響，延誤育苗系統的建成及導致魚苗損失；
- 2020年起，受疫情影響，魚苗供應不穩定及國際運輸亦受阻，以及提升供電系統工程於2020年7月才完成，2020年的第1批及第2批魚苗到港時間延遲至8月及10月；
- 受疫情持續影響，酒樓食肆生意大受打擊，間接影響海鮮及活魚市場供求，養殖魚出路減少，業界生意前景未明，引致投資及入苗意慾大減，嚴重影響項目發展，包括育苗器成功飼養的幼魚推廣；
- 本項目至2021年2月有第一次賣魚收入，項目所有幼魚已於2021年9月售出。收入未足以維持日常運作開支，有現金流問題。

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(3) 尋找方法及資金處理已嚴重燒毀的育苗器。

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9. 為解決問題所採取的補救措施及這些措施的成效（如有）

(1) 見附件(2)，表 2.4。

(2) 本著協助本港海水養魚戶及業界持續發展的信念，我們願意自行投放額外資源，完成項目。為解決現金流問題，實驗室早前自行注資，投放額外資金改善系統設備，並支付育苗系統的基本開支，維持日常運作。

(3) 我們於 4 月 13 日，與秘書處開會討論，了解各個處理育苗器的可行性。由於育苗器已嚴重燒毀，實驗室自行注資找供應商棄置育苗器，時間表如下，見**附件**(3):

日期	內容
2021 年 4 月 13 日	• 與秘書處開會討論。
2021 年 4 月 23 日	• 去信秘書處申請提早處理項目資產。先嘗試尋找對育苗器有興趣的買家，當中包括業界人士及養魚戶，將育苗器轉售。如果沒有買家，便會安排棄置育苗器。
2021 年 7 月 6 日	• 就有關棄置育苗器申請，署方通知我們，原則上批准有關提早處理項目資產的申請(見**附件**(3.1))。
2021 年 10 月 19 日	• 就有關棄置育苗器發出投標文件給 7 間服務供應商(見**附件**(3.2))。
2021 年 10 月 26 日	• 截標，共收到 7 間供應商回覆，當中只有 3 間提供報價(見**附件**(3.3))。
2021 年 11 月 8 日	• 經財務處審批投標結果後，向供應商發出採購文件(見**附件**(3.4))。供應商開始準備移除育苗器。
2022 年 1 月 7 日	• 供應商到魚排移除育苗器，利用拖船將育苗器運到醉酒灣、進行拆卸工程(見**附件**(3.5))。

10. 列出項目的出品（報告書、唯讀光碟等）、已製備的宣傳物料或印刷品（如有）
（請註明種類和數目，並各提供兩個副本）

活動海報，見**附件(1)**。

以下是第 3 次研討會的錄像連結，可供公眾在互聯網上觀看：

	https://cityu.zoom.us/rec/share/M2BCIsiATCWJNFGdmKWR05gmq4uLi_mpu4Y7DMb-sfzNp6wjizTK8f8-0ScK0ZJp.7SVP-QcTpo5eC4L1

育苗器設備及日常操作手冊，見**附件(4)**。以下是可供下載的連結或二維碼：

	https://drive.google.com/file/d/1HXkqg52kp3cmWvVGqXgyFDu1X1XgR4nu/view?usp=sharing

11. 財務報告(*請根據協議內訂明另外提供經審計賬目，可參考夾附的文件清單及樣本*)

a) 整體狀況

截至 1.4.2021 的開始結餘： -152,712.73 元

*加上*報告期間的收入： 由 1.4.2021 至 30.9.2021

共 12,600.00 元

(*金額與「收入分項數字詳情」的總和一致*)

*減去*報告期間的支出： (7,354.18) 注(1) 元

(*金額與「收入分項數字詳情」的總和一致*)

截至 30.9.2021 的結餘： -132,758.55 元

注(1): 由於項目收入低於計劃預算，SFDF 在計算上一期支出時需扣除利息收入，將前期和本期費用轉出，由其他項目資金支付。

b) 收入分項數字詳情（包括項目利息）

細項	用途	金額（港元）
利息收入		0.00
項目賣魚收入 (Note no. 20211021)		12,600
	總計	12,600

c) 支出分項數字詳情

代號	細項 (*請根據資助協議的「獲批項目」填寫*)	批准預算 (*請根據資助協議的「獲批項目開支」填寫。如有獲批的預算調撥，則填寫經調整後的最新金額*)	實際開支 (*提供所有收據正本*)	預計開支 (*預計下一報告期內開支*)	數量 (*請根據資助協議的「獲批項目」填寫*)	申請者的單據／收條編號 (*請將所有單據／收條編配一套號碼並適當填寫*)
	員工開支					
M1	員工開支: 1.項目統籌助理	$540,000	$0	$0	--	--
M2	員工開支: 2.研究助理	$360,000	$0	$0	--	--
	設備開支					
E1	設備: 濾水系統（清毒裝置及紫外光燈，生物過濾及化氨箱，沉澱及除雜質箱，過濾棉）	$200,000	$0	$0	--	--
E2	設備: 魚網養殖箱及後備魚	$50,000	$0	$0	--	--

	網					
E3	設備：寮更亭及簷蓬	$56,000	$0	$0	--	--
E4&E5	設備：大容量雙層玻璃纖維魚缸、發電機、防水電力裝置等設備)	$1,284,000	$0	$0	--	--
E6	設備：新建的塑料製新式魚排(約 700 平方米	$520,000	$0	$0	--	--
	營運開支					
G1	魚排營運：魚苗(9 批)	$1,890,000	$0	$0	--	--
G2	魚排營運：魚糧(餵飼魚苗)	$360,000	$0	$0	--	--
G3	魚排營運：魚糧(餵飼成魚)	$918,000	$0	$0	--	--
G4	魚排營運：電費/燃料費(魚苗池氣泵、加暖及循環系統)	$420,480	($3,839.30) (見註(1))	$0	--	
G5	魚排營運：硬件及設備維修(以每年 5%成本價計算);	$367,500	$0	$0	--	--
G6	魚排營運：分析及測試消耗品	$144,000	$0	$0	--	--
G7	魚排營運：負責南丫島魚排日常管理。[redacted] 香港優質水產養殖業發展協會負責	$1,642,500	$0	$0	--	
G8	魚排營運：電力安裝	$200,000	$0	$0	--	--
G9	魚排營運：保險費用、審計費用、預備報告費用及雜項	$140,000	($3,514.88) (見註(1))	$0		
G10	魚排營運：6 次業界工作坊	$60,000	$0	$0	--	--
G11	魚排營運：2 次公開推廣	$20,000	$0	$0	--	--
G12	魚排營運：宣傳及推廣籌備工作（搜集數據、編製資料、製作小冊子、powerpoint 及影片簡報等）	$100,000	$0	$0	--	--
		總計	**($7,354.18) (見註(1))**			

註(1): 由於項目收入低於計劃預算，SFDF 在計算上一期支出時需扣除利息收入，將前期和本期費用轉出，由其他項目資金支付。

12. 申請發放最後一筆資助款項的金額（如有）

扣除利息收入後，**申請發放最後一筆資助款項 HKD132,758.55。**

13. 須歸還政府的餘款數目（如有）

N/A

<完>

文件清單

		是	否 *(請於備註提供原因)*	有關文件/備註
1	已根據資助協議要求，另外提交財務報表／經審計賬目。 *(財務報表包括財務狀況表(資產負債表)及收入支出表；經審計賬目包括核數師報告（包括證明受資助者按照批撥條件使用資助額的聲明）、財務狀況表(資產負債表)、收支表、現金流動表及其他附註解釋資料。) 收支表須清楚列明各收入及支出細項(參考協議 Schedule II 內的獲批預算)，有關收入及支出細項應為經審計帳目內的一部分，受資助者有責任通知核數師有關要求。)*	☑	☐	
2	確認另外提交的財務報表／經審計賬目與進度／年度報告書的財務資料一致。 如資料不一致，請另外說明。	☑	☐	
3	就「項目收入」，除政府資助金額外，確認已提交其他收入的證明及內容。	☑	☐	
4	除利息收入、政府資助及已於申請書明的預計收入外，報告期沒有其收入。 如有非申請書聲明的其他收入，請說明相關性質及提供證明。	☑	☐	
5	就員工開支，確認已提交「薪金簽收單」及各員工的對應「強積金供款確認書」。	☐	☑	不適用
6	確認項目所有員工於項目期間只進行項目的相關工作。	☐	☑	不適用
7	如「獲批項目開支」與資助協議內的原金額不同，確認所有經調整的「獲批項目開支」已預先向秘書處申請並獲得批准。	☑	☐	獲批項目開支與資助協議內的原金額相同，各細項超支部分由本機構行承擔。

附件例表：

附件(1) 項目活動概要

附件(2) 項目進度及成效評估/ 補救方案

附件(2.1) 養殖水質及魚病記錄

附件(2.2) 生態養殖參考文章

附件(3) 棄置育苗器的程序

附件(4) 育苗器設備及日常操作手冊

附件(5) 經審計帳目及相關紀錄

附件(1)

項目活動概要

附件(2)

項目進度及

成效評估/ 補救方案

附件(2.1)

項目設施及現狀

附件(2.2)

養殖水質及魚病記錄

附件(2.3)

生態養殖參考文章

附件(3)

棄置育苗器的程序

附件(4)

育苗器設備及日常操作手冊

附件(5)

經審計帳目及相關紀錄

附件(1)：項目活動概要

表 1.1 活動概要 - (1) 養殖工作。

擬議活動 （包括項目的籌備及招募等）	日期 (20220131 修訂)	地點	目的及內容	預計參加人數
2017 年養殖工作	2017 年 4-12 月	南丫島蘆荻灣	- 籌備魚排設施、採購及建設。	
2018 年養殖工作	2018 年 1-5 月	南丫島蘆荻灣	- 籌備魚排設施、採購及建設。	
	2018 年 5-6 月	南丫島蘆荻灣	- 完成魚排主要設施採購程序。	
	2018 年 7 月	南丫島蘆荻灣	- 7 月完成主要設施建設;	
	2018 年 8 月	南丫島蘆荻灣	- 測試(育苗器及海水循環過濾系統等)設施運作。	
	2018 年 9 - 12 月	南丫島蘆荻灣	- 魚排系統開始運作。 - 進口(第 1 批)魚苗 (約 2.5 吋 石斑魚種，沙巴龍躉約 20,000 尾，龍躉約 5,000 尾) , 開始第 1 次中間育成。 - 檢討系統設施、餌料成效與魚的生長狀況，進一步改善計劃。	
2019 年養殖工作	2019 年 1-4 月	南丫島蘆荻灣	- 檢討 2018 年第 1 批魚苗的失敗個案，進一步完善系統設施及改善計劃。	
	2019 年 5-6 月	南丫島蘆荻灣	- 進口(2019 年第 1 批)魚苗 (約 2.5 吋 石斑魚種，沙巴龍躉約 5,500 尾)，開始中間育成。	

	2019 年 10-12 月	南丫島蘆荻灣	- 沙巴龍躉幼魚(2019 年第 1 批)轉放飼養網箱; - 進一步改善系統設施及計劃。	
2020 年養殖工作	2020 年 1-7 月	南丫島蘆荻灣	- 完善系統設施，申請提升供電及系統設備。	
	2020 年 8 月	南丫島蘆荻灣	- 進口(2020 年第 1 批) 花尾龍躉魚苗，約 5,700 尾。	
	2020 年 10 月	南丫島蘆荻灣	- 花尾龍躉幼魚(2020 年第 1 批) 共約 1,400 尾轉放網箱飼養，約 4,300 尾於系統中繼續飼養; - 進口(2020 年第 2 批) 花尾龍躉魚苗，約 6,300 尾。	
2020 年養殖工作 2021 年養殖工作	2020 年 10-12 月 2021 年 1-3 月	南丫島蘆荻灣	受疫情影響，以下事項順延： - 與業界人士交流意見、分享經驗。 - 由於入秋後天氣開始轉冷，水溫逐漸下降，不會於 2020 年內輸入第 3 批魚苗。	
2021 年養殖工作	2021 年 2-9 月	南丫島蘆荻灣	- 小範圍推廣幼魚; - 部分花尾龍躉幼魚已於 2021 年 2 月 26 日早上售出，分別有兩個批次： 1. 於 2020 年 8 月進口的第一批花尾龍躉幼魚 2500 尾，每尾$55 (每尾約 16cm， 130-140g) 2. 於 2020 年 10 月進口的第二批花尾龍躉幼魚 2800 尾，每尾$35 (每尾約 12cm， 20-25g) 共售出 5300 條，收入共$235,500 元正。 - 最後剩餘的花尾龍躉幼魚已於 2021 年 09 月 31 日售出，全部同屬於 2020 年 8 月進口的第 1 批花尾龍躉幼魚，共售出 180 尾，每尾$70 (每尾約 25cm，800-1000g)，收入共$12,600 元正。	

	2021 年 2-9 月	南丫島蘆荻灣	- 由於 2021 年 2 月 26 日晚上，項目魚排發生火警事故，育苗器有三分之一已嚴重燒毀，有結構安全問題，結構重組前不能再運作。 - 我們於 3 月初向秘書處表示，基於時間及資金有限，預計未能於項目完結前完成育苗器的維修工作，以致項目未能達到部分成效指標而有意提早結束題述項目。我們於 4 月 13 日，與秘書處開會討論，了解提早結束項目的可行性。我們於 4 月 23 日申請提早結束題述項目。 - 報告期間秘書處通知，可以提早處理受火警損壞的育苗器。由於沒有適合買家，未能轉售，實驗室已按程序尋找供應商棄置育苗器，詳見報告第 9 項。	
	2021 年 5 月	南丫島蘆荻灣	- 與業界人士交流意見、分享經驗。	

表 1.2 活動概要(2)：技術交流、宣傳及推廣工作。

擬議活動	日期 (20220815 修訂)	地點	目的及內容	參加人數/ 預計參加人數
業界研討會及工作坊	2021 年 5 月 13 日	香港漁民團體聯會 香港仔成都道 14-18 號茂盛大廈 2 字樓 B 座	舉辦第 1 次研討會及工作坊 用電腦幻燈片向養殖業界介紹項目、育苗系統運作及分享經驗。	12 人 (受疫情影響，預計參加人數由 50 人減至 15 人) 第 1 次研討會海報及情況，見圖 1.1。
業界研討會及工作坊	2021 年 5 月 27 日	香港漁民團體聯會 香港仔成都道 14-18 號茂盛大廈 2 字樓 B 座	舉辦第 2 次研討會及工作坊 用電腦幻燈片向養殖業界介紹項目、育苗系統運作及分享經驗。	12 人 (受疫情影響，預計參加人數由 50 人減至 15 人) 第 2 次研討會海報及情況，見圖 1.2。
業界研討會及工作坊	2022 年 (按疫情及需求)	社區會堂/漁民便利地點	舉辦第 3 次研討會及工作坊	提供研討會的錄像連結，可供公眾在互聯網上觀看
業界研討會及工作坊	2022 年 (按疫情及需求)	社區會堂/漁民便利地點	舉辦第 4 次研討會及工作坊	
公開推廣、宣傳和教育活動	2022 年 7 月 29 日	網上研討會	第 3 次研討會 (第 1 次公開講座) 用電腦幻燈片向養殖業界介紹項目、育苗系統運作及分享經驗。	70 - 80 人 (受疫情影響，預計參加人數由 100 人減至 50 人) 第 3 次研討會海報及情況，見圖 1.3。
公開推廣、宣傳和教育活動	2022 年 (按疫情及需求)	待定	第 2 次公開講座	提供研討會的錄像連結，可供公眾在互聯網上觀看

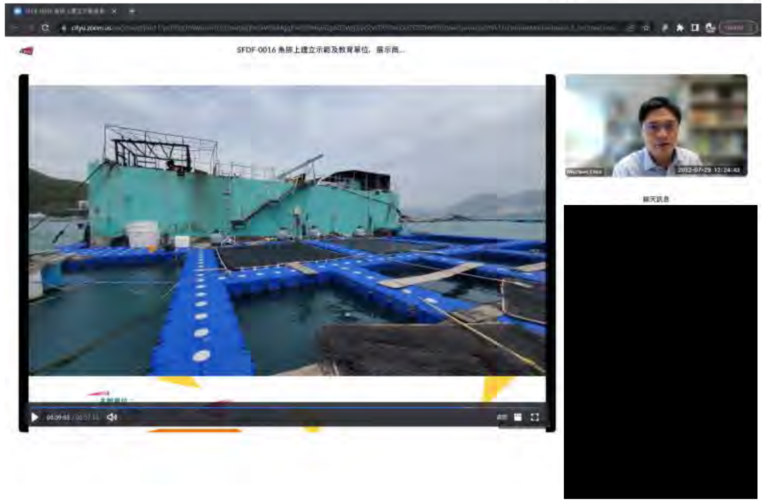
圖 1.1 第 1 次研討會海報及情況。

圖 1.2 第 2 次研討會海報及情況。

圖 1.3 第 3 次研討會(第 1 次公開講座)海報及情況。

以下是第 3 次研討會的錄像連結，可供公眾在互聯網上觀看：

https://cityu.zoom.us/rec/share/M2BCIsiATCWJNFGdmKWR05gmq4uLi_mpu4Y7DMb-sfzNp6wjizTK8f8-0ScK0ZJp.7SVP-QcTpo5eC4L1



附件(2)：項目進度及成效評估

表 2.1 項目進度及成效評估

	現在育苗器有三分之一已嚴重燒毀，有結構安全問題，不能再運作，以致項目未能達到部分成效指標。以下是項目進度的相關資料。 補救方案見附件(2) ，表 2.4。	
（1）	受是次事件影響的成效指標及項目成果；	➔ 有三份之一育苗器已燒毀，主要電力裝置及循環系統不能運作。因此， • 未能再養殖新一批魚苗作幼魚出售或示範用途； • 未能按排養殖業界／團體參觀作項目示範、技術交流或宣傳； • 未能從幼魚各批次中保留部份，作長期飼養及觀察至成魚出售，作為平衡質素追蹤。
（2）	各成效指標及項目成果進度；	
	(a) 優化魚苗育成；	➔ 於 2019 年，在採納各方(包括城大獸醫及循環系統專家，漁護署專家及基金秘書處人員)意見及建議下已成功飼養一批沙巴龍躉魚苗，並於同年 10 月轉放網箱飼養，預期 2020 年初出售成魚。雖然數量不多，預計收入並不足以支持項目日常運作開資，但本着幫助香港海水養魚戶及養魚業持續發展為目標，本機構及協辦都願意幫助香港海水養魚戶及養魚業持續發展，繼續投放資源以承擔完成項目的責任。 • 綜合多次測試的經驗及過濾系統的承載能力，本機構於 2019 年向署方及委員會申請在項目總資助額不變的情況下修改項目方案，以建立成功例子作示範及教育單位為目標，以完成項目。修訂方案計劃如下: 1. 延長原訂項目完成日期(2020 年 3 月 31 日)18 個月，至 2021 年 9 月 30 日; 2. 減少入苗次數，由九次減少至三次; 3. 減少每次入苗數量，由 30000 尾減少至 12000 至 14000 尾，以降低過濾系統的負荷; 4. 更改入苗時間: 主要集中在四至九月期間入苗，此時海水温暖魚苗生長速度較快; 5. 縮短魚苗在系統中的養殖時間，由四個月減至兩個月: 如在春夏期間入苗，魚苗兩個月內已達到可網箱放養的大小(即五吋或 150g);

		• 原先預計 2020 年 4 至 9 月期間飼養三批魚苗，部分轉售漁民於網箱放養，部分於 2021 年作成魚出售。 • 2020 年成功飼養兩批分別 8 月及 10 月進口的花尾龍躉魚苗，幼魚存活率分別高於 98%及 75%，並於 2021 年 2 月 26 日售出。 ➔ 受疫情影響，魚苗供應不穩定及國際運輸亦受阻，以及提升供電系統工程於 2020 年 7 月才完成，2020 年的第 1 批魚苗(花尾龍躉 5,700 尾)到港時間延遲至 8 月。第 2 批魚苗(花尾龍躉 6,300 尾)到港時間順延至 2020 年 10 月。由於入秋後天氣開始轉冷，水溫逐漸下降，與魚排負責人[redacted]商討後決定不會於 2020 年內輸入第 3 批魚苗。 ➔ 由於育苗器已嚴重燒毀，未能於 2021 年再養殖第 3 批魚苗。 ➔ 受疫情持續影響，酒樓食肆生意大受打擊，間接影響海鮮及活魚市場供求，養殖魚出路減少，業界生意前景未明。雖然投資及入苗意慾大減，但有個別團體或公司對我們的海上育苗器有興趣，有嘗試討論未來合作的可行性； • 2021 年 1 月一間私人公司[redacted]有興趣購買花尾魚苗，並嘗試在陸上養魚場飼養； • 部分花尾龍躉幼魚已於 2021 年 2 月 26 日早上售出，分別有兩個批次： 1. 於 2020 年 8 月進口的第一批花尾龍躉幼魚 2500 尾，每尾$55 (每尾約 16cm， 130-140g) 2. 於 2020 年 10 月進口的第二批花尾龍躉幼魚 2800 尾，每尾$35 (每尾約 12cm， 20-25g) 共售出 5300 條，收入共$235,500 元正，交易[redacted]代為處理，收款後再存入城大／項目戶口。 • 雖然已於幼魚各批次中保留部份，但由於 2021 年 2 月 26 日(於售出 5300 條幼魚的同一日)，項目魚排發生火警事故，育苗器有三分之一嚴重燒毀，大部份保留下來的幼魚已死亡。雖然有部份幼魚已轉至魚排網箱，幼魚受驚以致食欲不振，狀態不佳而繼漸死去，未能觀察至成魚出售。 剩餘的花尾龍躉幼魚已於 2021 年 09 月 31 日售出，全部同屬於 2020 年 8 月進口的第 1 批花尾龍躉幼魚，共售出 180 尾，每尾$70 (每尾約 25cm，

		800-1000g)，收入共$12,600 元正。交易[redacted]代為處理，收款後再存入城大／項目戶口。
	(b) 為養殖戶示範魚苗育成系統的結構及製作運作手冊	➔ 為養殖戶示範魚苗育成系統的結構 • 因疫情關係，至今仍沒有安排大型講座及參觀活動。我們曾透過[redacted]，向不同個別養魚戶及私人公司簡介本項目目的及宗旨，推介海上循環系統養殖設施及花尾魚苗。 • 2020 年 11 月，我們協助秘書處按排的攝影隊伍拍攝項目宣傳片，大眾可於 AFCD 漁農自然護理署的 Youtube 頻度觀看。 https://www.youtube.com/watch?v=GI3IHDzJgR8 • 2021 年 2 月[redacted]於 CityU RESEARCH 刊物 (只供英文版) 簡介紹本項目目的及宗旨，章節: 健康一體化 page 16 - 17。 https://www.cityu.edu.hk/zh-hk/research/overarching-research-themes https://www.cityu.edu.hk/system/files/2021-02/CityUResearch.pdf • 有關系統及魚苗推廣活動，本預計在 2021 年農曆新年後，會嘗試以小組形式進行，安排業界及有興趣人仕參觀育苗系統；由於育苗器已嚴重燒毀，未能按排養殖業界／團體參觀作項目示範或宣傳。 • **已於 2021 年 5 月 6 日及 5 月 13 日安排兩個講座給業界及有興趣人仕，以電腦幻燈片形式向養殖業界介紹項目、育苗系統運作及分享經驗。** • 活動海報及情況，**見附件(1) - 圖 1.1 及 1.2**。
		➔ **運作手冊（育苗器設備及日常操作手冊），已於 2021 年 8 月制訂完成。於 2022 年 1 月，再次修訂，加入乾式飼料、電力系統維護及防火相關資料。見附件(4)。**
（3）	項目魚排內養殖魚類數量及收入；	
	項目於 2020 年 8 月進口 2020 年第一批花尾龍躉魚苗約 5,700 尾的去向；	• 根據計畫書，預計每一批魚苗在售出前的損失率為 30%，預計存活率 70%，即 3990 尾可作魚苗出售。如將魚苗留下飼養作成魚出售，預計當中存活率 70%，即約 2793 尾可作成魚出售； • 由於 2020 年 12 月尾至 2021 年 1 月中，寒流襲港，氣溫反覆升跌，蘆荻灣海水溫度曾跌至 16.3 ℃，有部分魚苗未能適應温差，低抗力下降，不適甚至死亡；

		• 2021 年 2 月，水溫回升至 18 ℃，存活下來的魚苗情況好轉。大約剩下約 3000 尾可供出售； • 2500 尾花尾龍躉幼魚已於 2021 年 2 月 26 日售出，每尾$55，收入共 $137,500 元正。 • 報告期間，項目魚排內養殖魚類數量見附件(2) ，表 2.2 及表 2.3。
	項目於 2020 年 10 月進口 2020 年第二批花尾龍躉魚苗約 6,300 尾的去向；	• 由於第二批魚苗品質和狀態不佳，到港一星期內已死去 500 尾，剩下 5800 尾。根據計畫書，預計每一批魚苗在售出前的損失率為 30%，預計存活率 70%，即 4060 尾可作魚苗出售；如將魚苗留下飼養作成魚出售，預計當中存活率 70%，即 2842 尾可作成魚出售； • 由於 2020 年 12 月尾至 2021 年 1 月中，寒流襲港，氣溫反覆升跌，蘆荻灣海水溫度曾跌至 16.3 ℃，有部分魚苗未能適應温差，低抗力下降，不適甚至死亡； • 2021 年 2 月，水溫回升至 18 ℃，存活下來的魚苗情況好轉。大約剩下約 3000 尾可供出售； • 2800 條花尾龍躉幼魚已於 2021 年 2 月 26 日售出，每尾$35，收入共 $98,000 元正。 • 報告期間，項目魚排內養殖魚類數量見附件(2) ，表 2.2 及表 2.3。
		• 剩餘的花尾龍躉幼魚已於 2021 年 09 月 31 日售出，全部同屬於 2020 年 8 月進口的第 1 批花尾龍躉幼魚，共售出 180 尾，每尾$70 (每尾約 25cm，800-1000g)，收入共$12,600 元正。

表 2.2 第四份年度報告報告期間（2020 年 4 月 1 日至 2021 年 3 月 31 日），項目魚排內養殖魚類數量。

第四份年度報告報告期間（2020 年 4 月 1 日至 2021 年 3 月 31 日）								
批次	入苗時間	品種	截至 2020 年 3 月 31 日 (第三份年度報告） 剩餘數目	放養魚苗數目	損失養魚數目	損失養魚原因	出售養魚數目	截至 2021 年 3 月 31 日 (第四份年度報告） 剩餘數目
第 1 批	2018 年 9 月	沙巴龍躉	0	--	--	--	--	0
第 2 批	2018 年 10 月	花尾龍躉	0	--	--	--	--	0
第 3 批	2018 年 10 月	沙巴龍躉	0	--	--	--	--	0
第 4 批	2018 年 11 月	沙巴龍躉	0	--	--	--	--	0
第 5 批	2019 年 6 月	沙巴龍躉	1850	1850	1400	這批魚於網箱放養後，曾發現魚鰓有寄生蟲，約 1400 尾於報告期間在網箱逐漸自然死亡。	0	450
第 6 批	2020 年 8 月	花尾龍躉	--	5700	2860	這批魚於 2020 年 8 月到步後狀態甚佳，於育苗器放養兩個月後只有約 120 尾逐漸自然死亡，存活率達 98%。 約 1672 尾於 2020 年 2 月於網箱放養後狀態不佳，逐漸自然死亡。 另外，於 2021 年 2 月 26 日，項目魚排發生火警事故，育苗器有三分之一嚴重燒毀，約 618 尾於火警中死亡。約 450 尾於火警時放到網箱後狀態欠佳，一個月內亦逐漸自然死亡。	2500	340
第 7 批	2020 年 10 月	花尾龍躉	--	6300	3500	這批魚有質量問題，約 1500 尾於 2020 年 10 月到步後狀態不佳不進食，於育苗器放養兩個月後逐漸自然死亡，存活率達 75%。 約 714 尾於 2020 年 12 月後未能適應水溫下降，狀態不佳不進食，於育苗器中逐漸自然死亡。 另外，於 2021 年 2 月 26 日，項目魚排發生火警事故，育苗器有三分之一嚴重燒毀，約 186 尾於火警中死亡。約 1100 尾於火警時放到網箱後狀態欠佳，一個月內逐漸自然死亡。	2800	0

表 2.3 期終報告書 (2021 年 4 月 1 日至 2021 年 9 月 30 日)，項目魚排內養殖魚類數量。

期終報告書 (2021 年 4 月 1 日至 2021 年 9 月 30 日）								
批次	入苗時間	品種	截至 2021 年 3 月 31 日 (期終報告書) 剩餘數目	放養魚苗數目	損失養魚數目	損失養魚原因	出售養魚數目	截至 2021 年 9 月 30 日 (期終報告書) 剩餘數目
第 1 批	2018 年 9 月	沙巴龍躉	0	--	--	--	--	0
第 2 批	2018 年 10 月	花尾龍躉	0	--	--	--	--	0
第 3 批	2018 年 10 月	沙巴龍躉	0	--	--	--	--	0
第 4 批	2018 年 11 月	沙巴龍躉	0	--	--	--	--	0
第 5 批	2019 年 6 月	沙巴龍躉	450	450	258	258 尾於報告期間在網箱逐漸自然死亡。	0	192 (由於這批魚苗屬城大及[redacted]自資購買作系統測試，[redacted]會繼續飼養。)
第 6 批	2020 年 8 月	花尾龍躉	340	340	160	160 尾於報告期間在網箱逐漸自然死亡。 180 尾於報告期間出售。	180	0
第 7 批	2020 年 10 月	花尾龍躉	0	0	0	--	0	0

表 2.4 項目設有 5 項成效指標，下表提供項目完結時進度/ 補救方案:

指標內容	項目完結時進度
(1) 出 產 25,200 至 29,400 尾幼魚或 17,640 至 20,580 尾成魚	**共售出幼魚 5300 尾及成魚 180 尾**。 詳程如下： ➔ 受疫情影響，魚苗供應不穩定及國際運輸亦受阻，以及提升供電系統工程於 2020 年 7 月才完成，2020 年的第 1 批魚苗(花尾龍躉 5,700 尾)到港時間延遲至 8 月。第 2 批魚苗(花尾龍躉 6,300 尾)到港時間順延至 2020 年 10 月。由於入秋後天氣開始轉冷，水溫逐漸下降，與魚排負責人[redacted]商討後決定不會於 2020 年內輸入第 3 批魚苗。 • 2020 年成功飼養兩批分別 8 月及 10 月進口的花尾龍躉魚苗，幼魚存活率分別高於 98%及 75%，並於 2021 年 2 月 26 日售出。 ➔ 由於育苗器已嚴重燒毀，未能於 2021 年再養殖第 3 批魚苗。 ➔ 受疫情持續影響，酒樓食肆生意大受打擊，間接影響海鮮及活魚市場供求，養殖魚出路減少，業界生意前景未明。雖然投資及入苗意慾大減，但有個別團體或公司對我們的海上育苗器有興趣，有嘗試討論未來合作的可行性； • 部分花尾龍躉幼魚已於 2021 年 2 月 26 日早上售出，分別有兩個批次： 1. 於 2020 年 8 月進口的第一批花尾龍躉幼魚 2500 尾，每尾$55 (每尾約 16cm，130-140g) 2. 於 2020 年 10 月進口的第二批花尾龍躉幼魚 2800 尾，每尾$35 (每尾約 12cm，20-25g) 共售出 5300 條，收入共$235,500 元正。 • 雖然已於幼魚各批次中保留部份，但由於 2021 年 2 月 26 日(於售出 5300 條幼魚的同一日)，項目魚排發生火警事故，育苗器有三分之一嚴重燒毀，大部份保留下來的幼魚已死亡。雖然有部份幼魚已轉至魚排網箱，幼魚受驚以致食欲不振，狀態不佳而繼漸死去，未能觀察至成魚出售。

	剩餘的花尾龍躉幼魚已於 2021 年 09 月 30 日售出，全部同屬於 2020 年 8 月進口的第 1 批花尾龍躉幼魚，共售出 180 尾，每尾$70 (每尾約 25cm，800-1000g)，收入共$12,600 元正。
(2) 1,000 本作業指南手冊作參考	已制作一本 育苗器設備及日常操作手冊 供業界參考，計劃只於網上及電子媒介發佈有關小冊子，以下是可供下載的連結或二維碼： Via Google Drive: https://drive.google.com/file/d/1HXkqg52kp3cmWvVGqXgyFDu1X1XgR4nu/view?usp=sharing
(3) 300 名漁民及 200 名公眾人士直接受惠於研討會、工作坊、公開講座及實地考察	**共 90-100 人次直接受惠於研討會、工作坊。** 詳程如下： ➔ 為養殖戶示範魚苗育成系統的結構 • 已於 2021 年 5 月 6 日及 5 月 13 日安排兩個講座給業界及有興趣人仕，以電腦幻燈片形式向養殖業界介紹項目、育苗系統運作及分享經驗。 共 24 名漁民及公眾人士直接受惠於研討會、工作坊。 • 有關系統及魚苗推廣活動，本預計在 2021 年農曆新年後，會嘗試以小組形式進行，安排業界及有興趣人仕參觀育苗系統；由於育苗器已嚴重燒毀，未能按排養殖業界／團體參觀作項目示範或宣傳。 ➔ 補救方案

	• 2020 年 11 月，我們協助秘書處按排的攝影隊伍拍攝項目宣傳片，大眾可於 AFCD 漁農自然護理署的 Youtube 頻度觀看。 https://www.youtube.com/watch?v=GI3IHDzJgR8 • 2021 年 2 月，林群聲及梁美儀教授於 CityU RESEARCH 刊物 (只供英文版) 簡介紹本項目目的及宗旨，章節: 健康一體化 page 16 - 17。 https://www.cityu.edu.hk/zh-hk/research/overarching-research-themes https://www.cityu.edu.hk/system/files/2021-02/CityUResearch.pdf • 已於 2022 年 7 月 29 日安排公開講座給業界及有興趣人仕，以網上形式利用電腦幻燈片形式向養殖業界介紹項目、育苗系統運作及分享經驗。共 70-80 名漁民及公眾人士直接受惠於研討會、工作坊。以下是第 3 次研討會的錄像連結，可供公眾在互聯網上觀看： https://cityu.zoom.us/rec/share/M2BCIsiATCWJNFGdmKWR05gmq4uLi_mpu4Y7DMb-sfzNp6wjizTK8f8-0ScK0ZJp.7SVP-QcTpo5eC4L1 • **實驗室亦會積極參與漁業持續發展基金舉辦的公開研討會，安排公開講座。**
(4) 把養殖水質 、 魚病記錄、飼料及漁產品（幼魚及成魚）相關的研究結果進行分析和整理，提交一份書面總結報告 (5) 把過程中發現的病原微生物及症狀記錄成冊，作為後續養殖病害防治的參考資料	養殖水質及魚病記錄，見附件(2.1) 。 養育魚苗時間表及飼料使用建議，請參閱本項目制作的育苗器設備及日常操作手冊。 另外，實驗室在生態養殖(Integrated Multi-Trophic Aquaculture， IMTA)方面有研究成果，實驗證明生態養殖可以應用於本地魚排，不但可以透過養殖扇貝(noble scallop *Mimachlamys nobilis*) 改善魚排周邊水質，亦可以增加養魚戶收入。建議育苗系統周邊的成魚網箱亦可實行相類似的生態養殖。 詳見以下文章及見附件(2.2a 及 2.2b) 。： • Wartenberg R, Fenga L, Wu JJ, Ma YM, Chan LL. Telfere TC, Paul KS Lam (2017) The impacts of suspended mariculture on coastal zones in China and the scope for Integrated Multi-Trophic Aquaculture. Ecosystem health and sustainability 3(6), [1340268]. https://doi.org/10.1080/20964129.2017.1340268 • Wartenberg R, Limbu K, Feng L, Wu JJ, Chan LL, Telfer TC, Paul KS Lam (2018). The Feasibility of Integrating the Noble Scallop *Mimachlamys nobilis* with Existing Fish Monoculture Farms in the South China Sea: A Bioeconomic Assessment from

	Hong Kong. Journal of Shellfish Research 37(3):635-650. https://doi.org/10.2983/035.037.0316
如 未 能 完 成 有 關 成 效 指 標 ， 補 救 方 案 ；	➔ 補救方案: 網上公開講座/研討會的錄像連結，可供公眾在互聯網上觀看 • 藉着公開講座及育苗器設備及日常操作手冊，與業界及公眾分享經驗。實驗室亦歡迎公眾隨時來電或電郵查詢。 • 以下是第 3 次研討會的錄像連結，可供公眾在互聯網上觀看：https://cityu.zoom.us/rec/share/M2BCIsiATCWJNFGdmKWR05gmq4uLi_mpu4Y7DMb-sfzNp6wjizTK8f8-0ScK0ZJp.7SVP-QcTpo5eC4L1

附件(2.1)：項目設施及現狀 - 受資助設施例表

Item	Description	Date of Purchase	Cost ($)	Quantity	Location	Date & Reason of Disposal	Project in-charge’s Signature	Remarks
1	濾水系統（清毒裝置及紫外光燈，生物過濾及化氮，沉澱及除雜質箱，過濾棉）	28 March 2018	268,000	1 部	南丫島蘆荻灣	火警事故後已損毀/已按程序報銷設施 7 January 2022	[redacted]	$200,000 為基金資助，其餘為本機購自行注資。
2	魚苗養殖水池纖維艙及儲水池	9 August 2017	1,118,000	1 組	南丫島蘆荻灣	火警事故後已損毀/已按程序報銷設施 7 January 2022	[redacted]	NA
3	發電機（20kW）及防水電器	9 August 2017	166,000	2 部	南丫島蘆荻灣	火警事故後已損毀/已按程序報銷設施 7 January 2022	[redacted]	NA
4	新建的塑料製新式魚排安裝連配件	29 August 2017	427,500	1 組	南丫島蘆荻灣	仍可使用	[redacted]	有意於項目完結後保留。 我們建議將魚排的組合浮台的擁有權直接轉移至協辦機構[redacted]或[redacted]名下，讓魚排負責人[redacted]可繼續使用設施作水產養殖，並可以向業界示範以組合浮台作為新式魚排，代替傳統(已拆卸)的木魚排。

附件(2.1) ：養殖水質及魚病記錄

育苗系統的水質

每天 24 小時，每小時記錄水質數據至少 6 次，包括水溫、溶解氧含量、鹽度、酸鹼度、氧化還原值及渾濁度，確保系統正常運作。

以下是 2020 年 8 月至 2021 年 1 月的水質記錄 ：

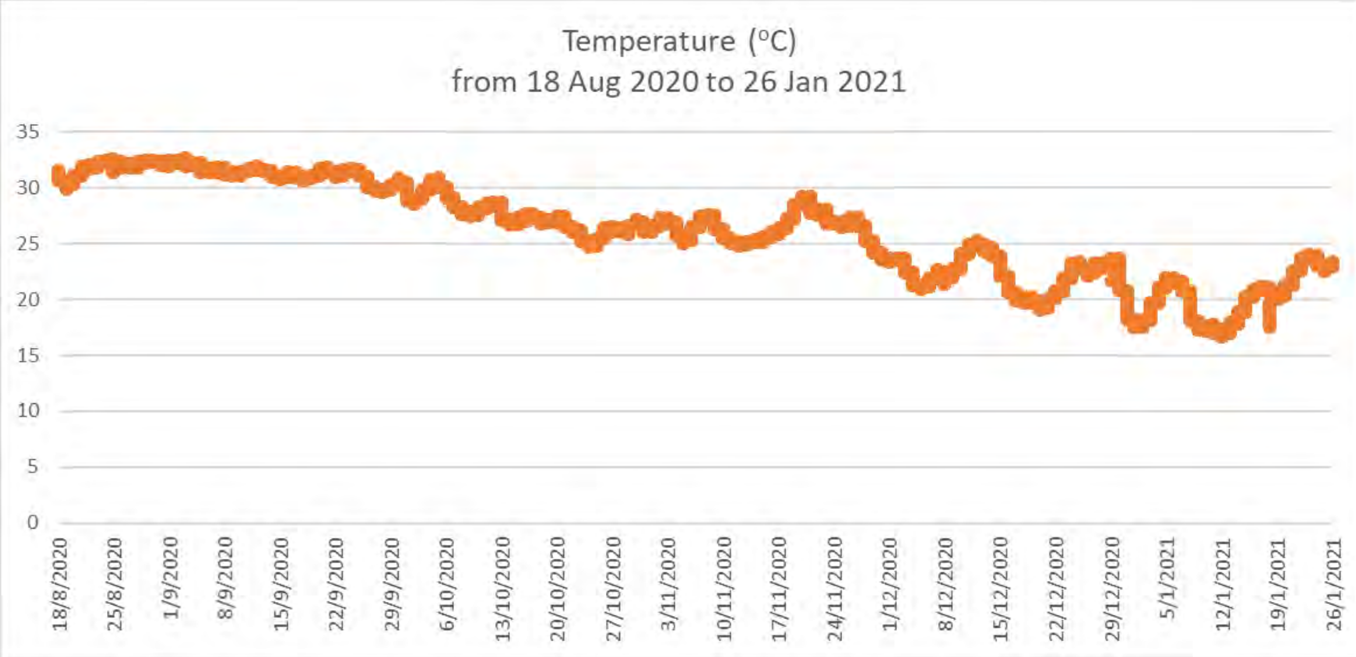
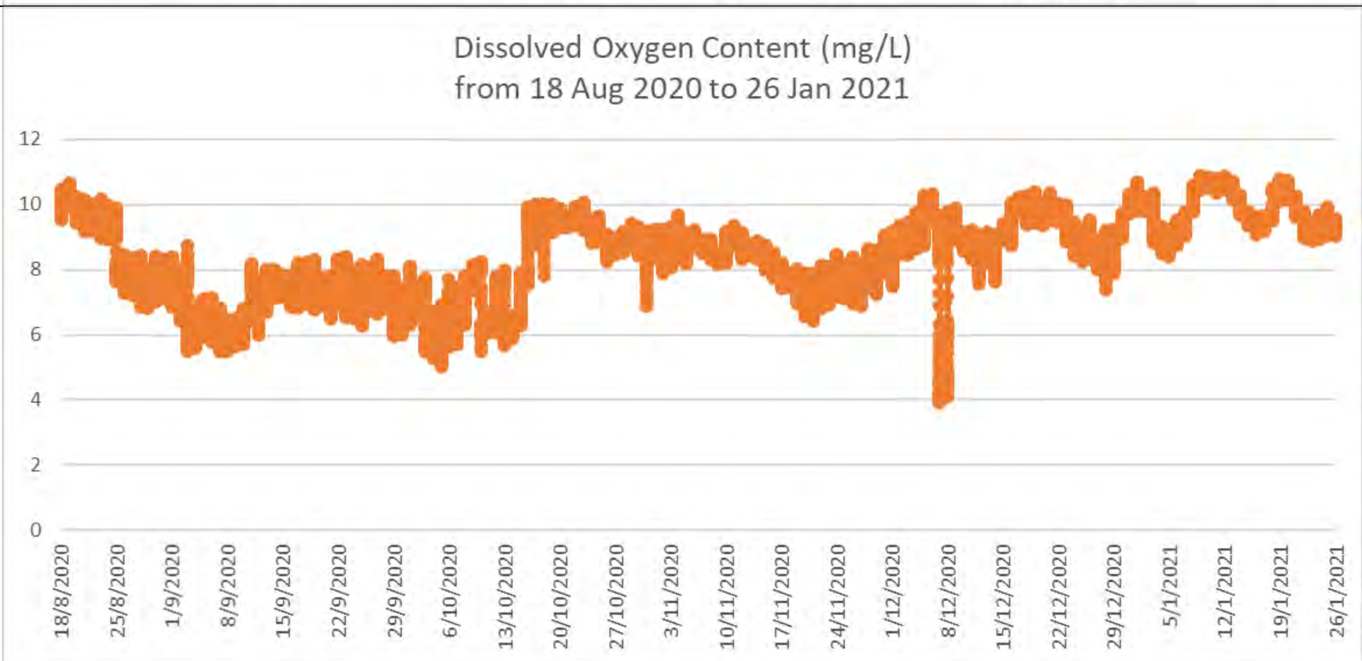
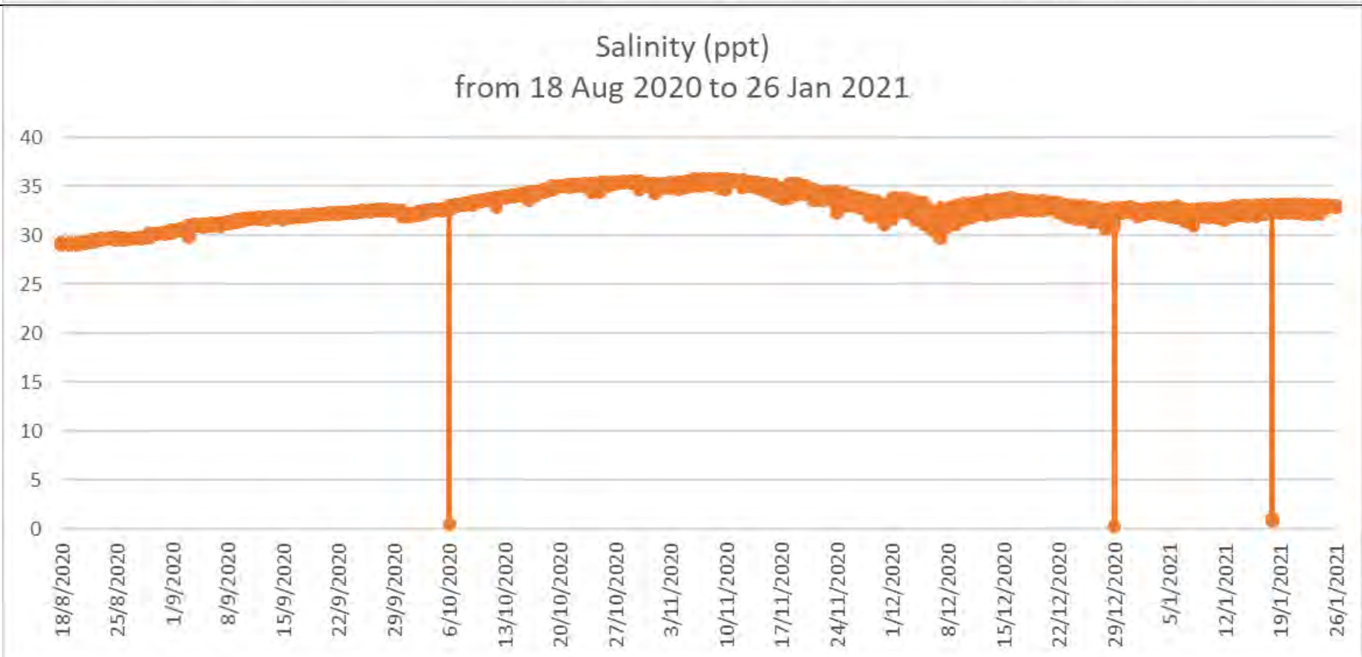
第一組循環系統(左邊) 數據，見圖 1：

每月平均	8 月	9 月	10 月	11 月	12 月	1 月
水溫 (℃)	31.76	31.23	27.43	26.31	22.10	20.11
溶解氧含量 (mg/L)	8.84	7.05	7.99	8.19	9.07	9.84
鹽度 (º/₀₀)	29.63	31.79	34.14	34.73	32.65	32.39
酸鹼度 (pH 值)	7.39	7.05	7.25	7.23	7.29	7.53
氧化還原值 (ORP mV)	327.33	360.25	321.18	343.97	314.22	314.95
渾濁度 (NTU)	1.34	-0.35	-0.16	-0.71	0.6	-0.90

第 2 組循環系統(右邊) 數據，見圖 2：

每月平均	8 月	9 月	10 月	11 月	12 月	1 月
水溫 (℃)	31.81	31.31	27.76	26.63	22.38	20.33
溶解氧含量 (mg/L)	11.16	7.29	7.57	7.27	9.14	12.23
鹽度 (º/₀₀)	28.77	31.66	33.15	32.93	32.71	32.72
酸鹼度 (pH 值)	7.52	7.05	7.03	7.01	7.06	7.36
氧化還原值 (ORP mV)	318.93	363.04	372.87	349.79	339.82	316.52
渾濁度 (NTU)	0.70	0.80	18.93	45.27	17.72	15.98

圖 1：育苗器水質監測數據 (2020 年 8 月 18 日至 2021 年 1 月 26 日) – 第一組循環系統(左邊)：(A) 水溫、(B) 溶解氧含量、(C) 鹽度、(D) 酸鹼度、(E) 氧化還原電(ORP) 值及 (F) 濁度。另外，總氨氮、亞硝酸鹽和硝酸鹽的含量分別維持低於 0.05、5 和 50 ppm 的水平。

	圖 1A：水溫
	圖 1B：溶解氧含量
	圖 1C：鹽度

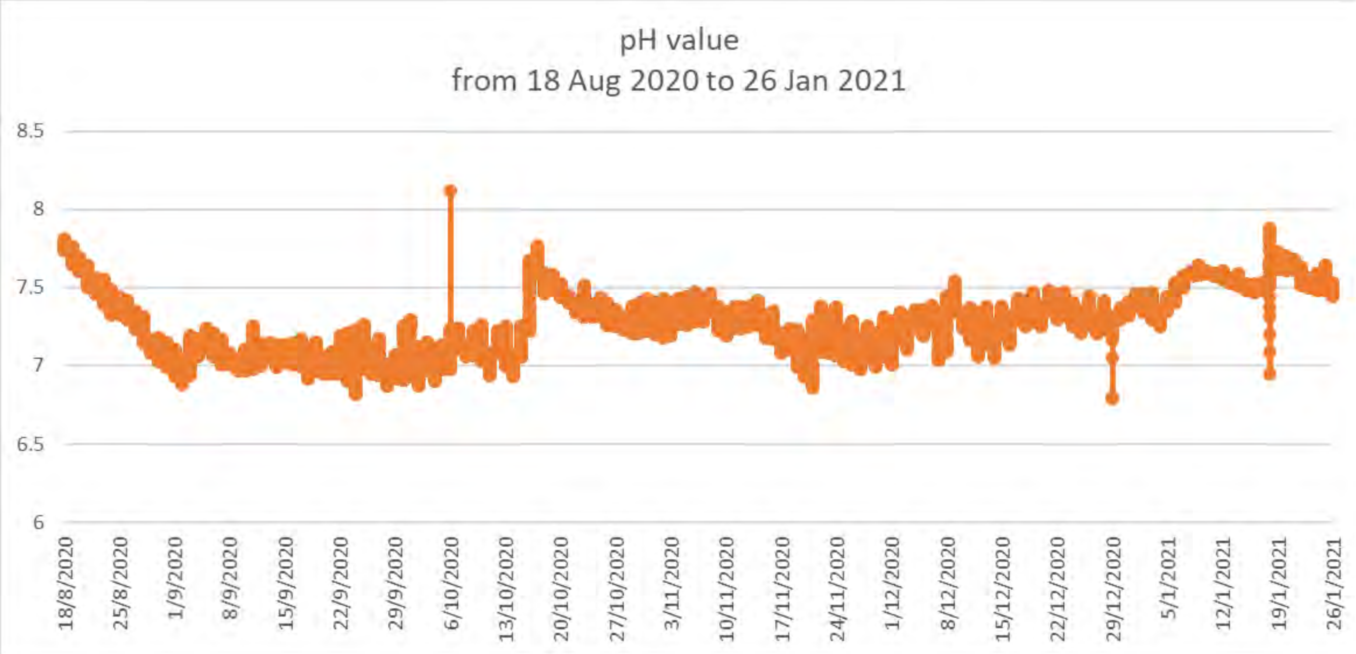
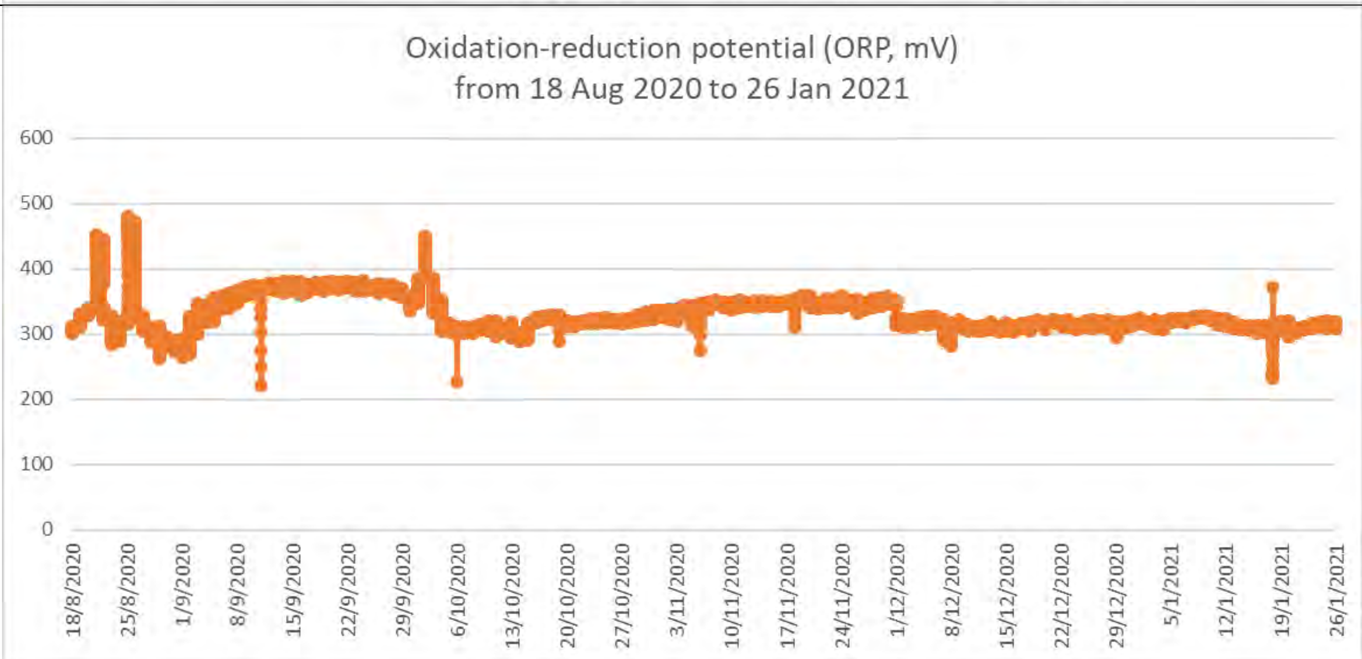
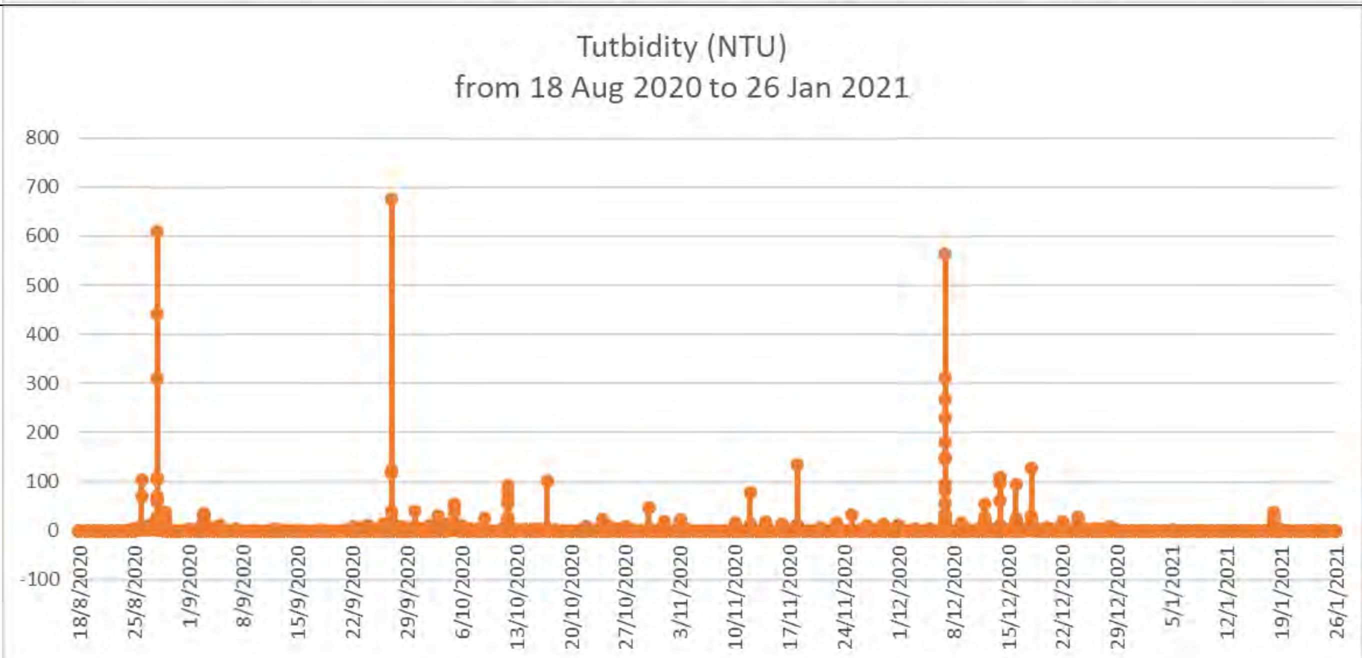
	圖 1D：酸鹼度
	圖 1E：氧化還原電位(ORP)值
	圖 2F：濁度

圖 2 : 育苗器水質監測數據 (2020 年 8 月 15 日至 2021 年 1 月 26 日) – 第 2 組循環系統(右邊)：(A) 水溫、(B) 溶解氧含量、(C) 鹽度、(D) 酸鹼度、(E) 氧化還原電(ORP) 值及 (F) 濁度。另外，總氨氮、亞硝酸鹽和硝酸鹽的含量分別維持低於 0.05、5 和 50 ppm 的水平。

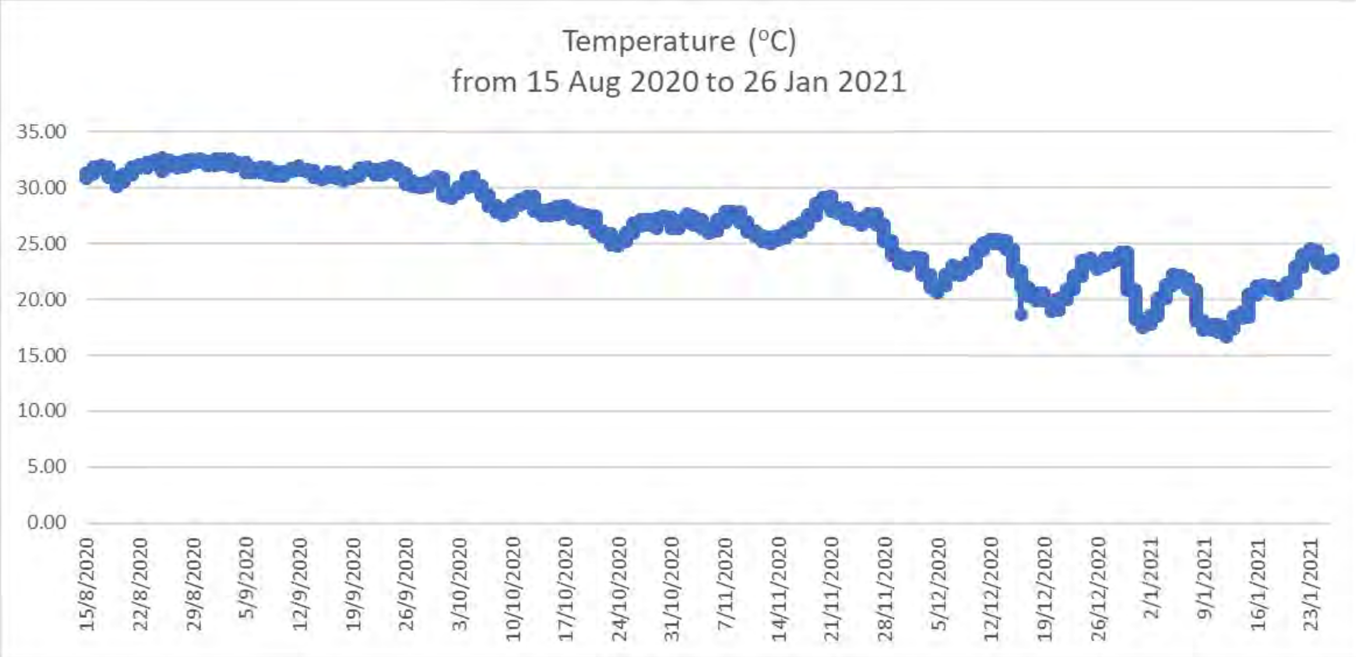


圖 2A：水溫

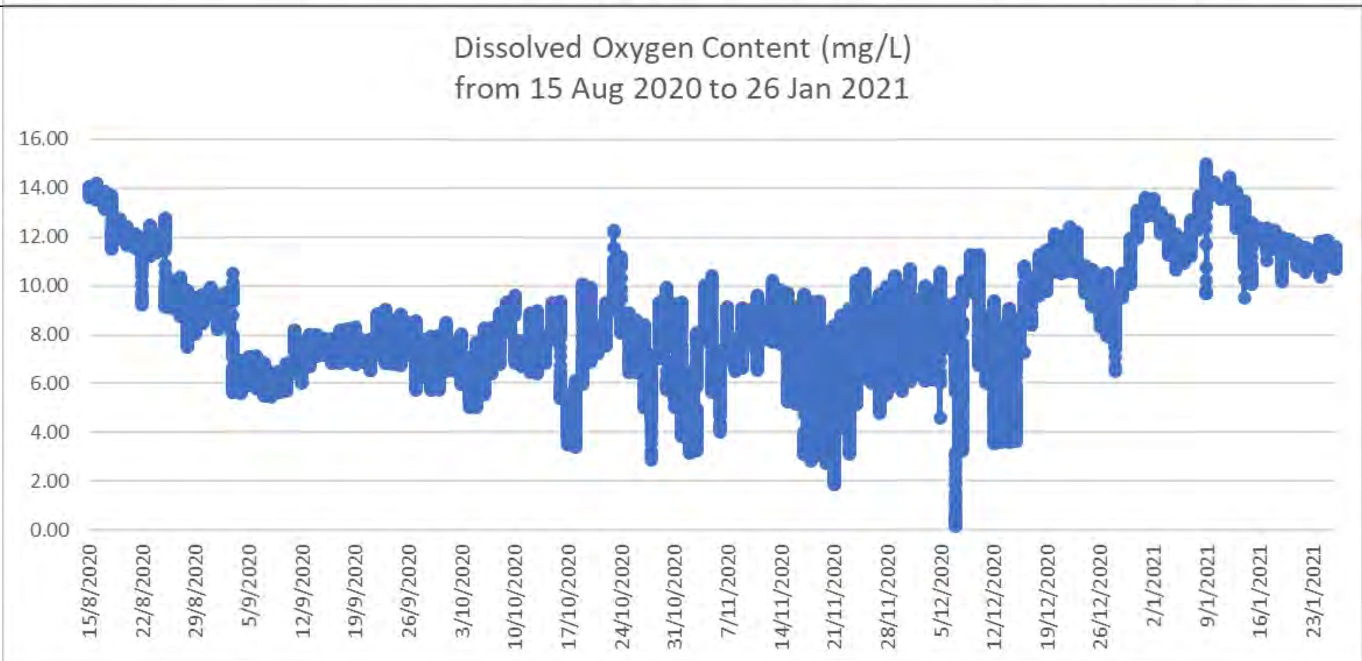


圖 2B：溶解氧含量

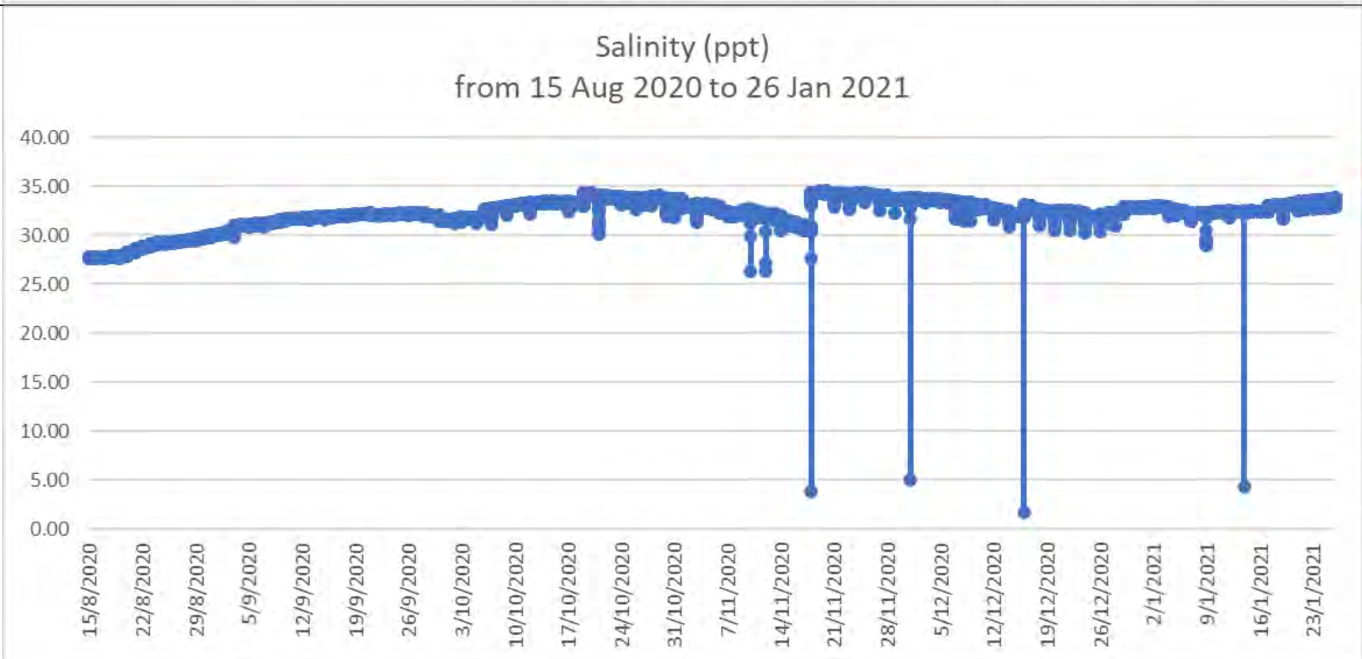


圖 2C：鹽度

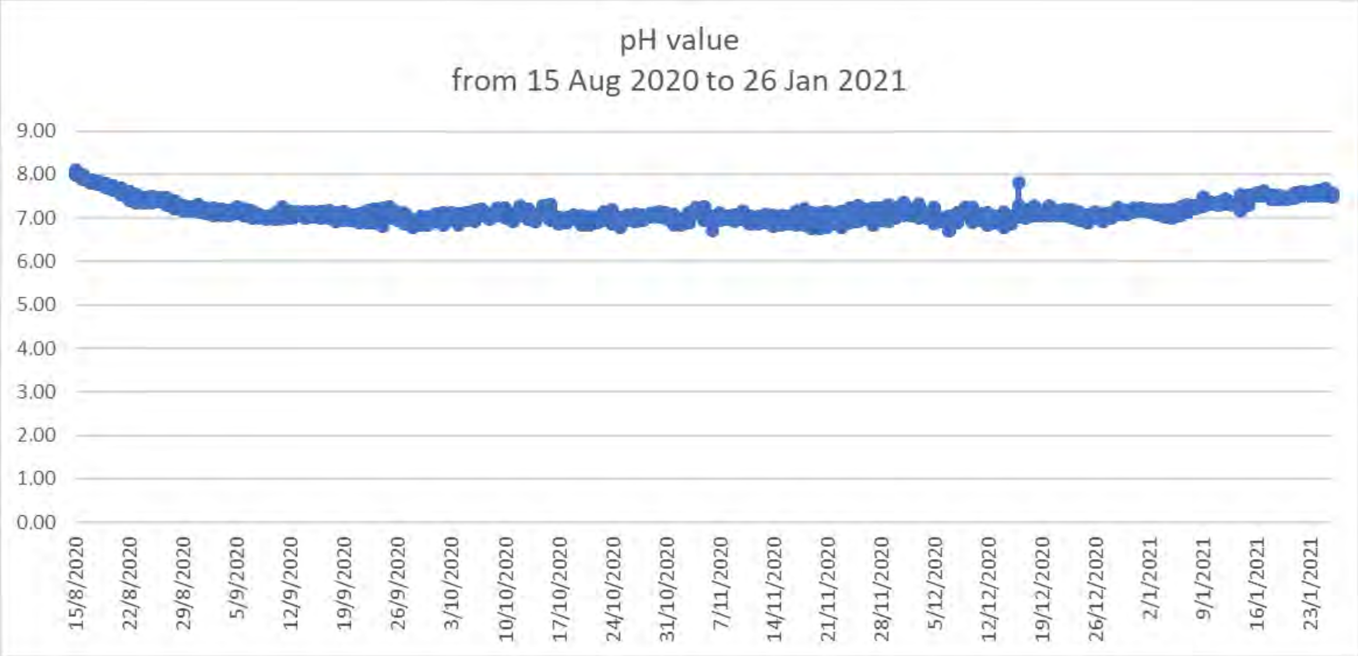


圖2D：酸鹼度

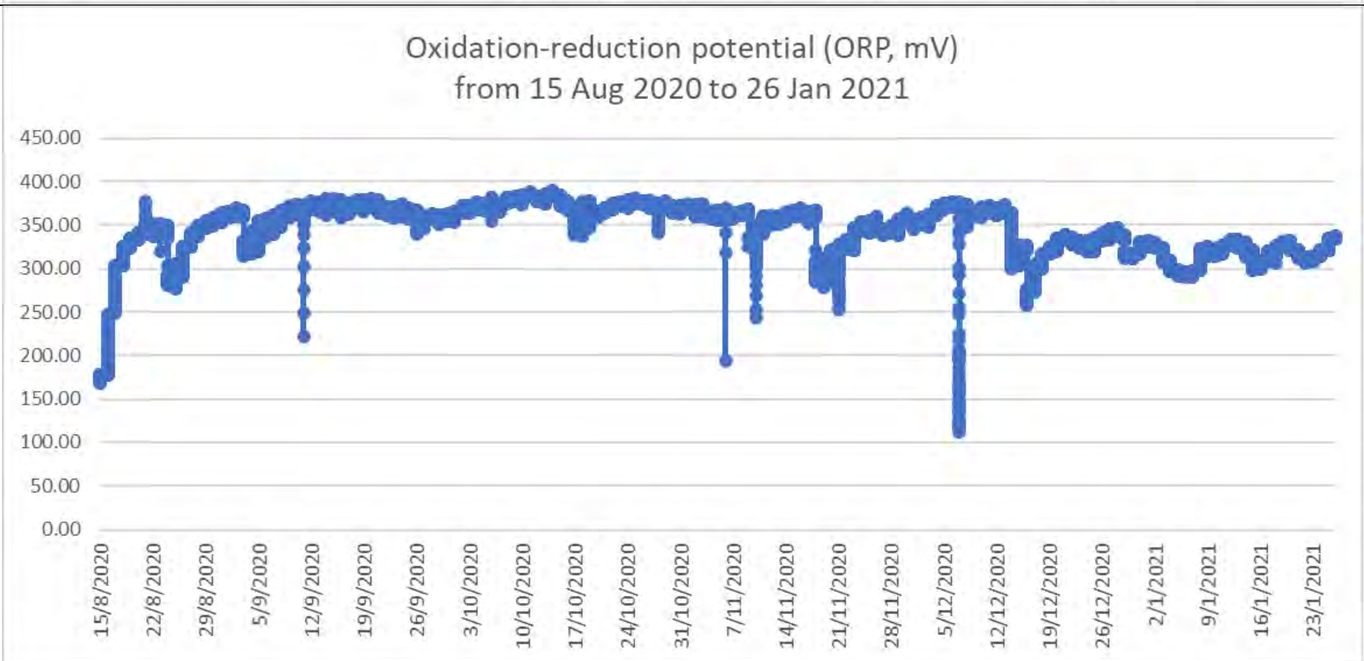


圖2E：氧化還原電位(ORP)值

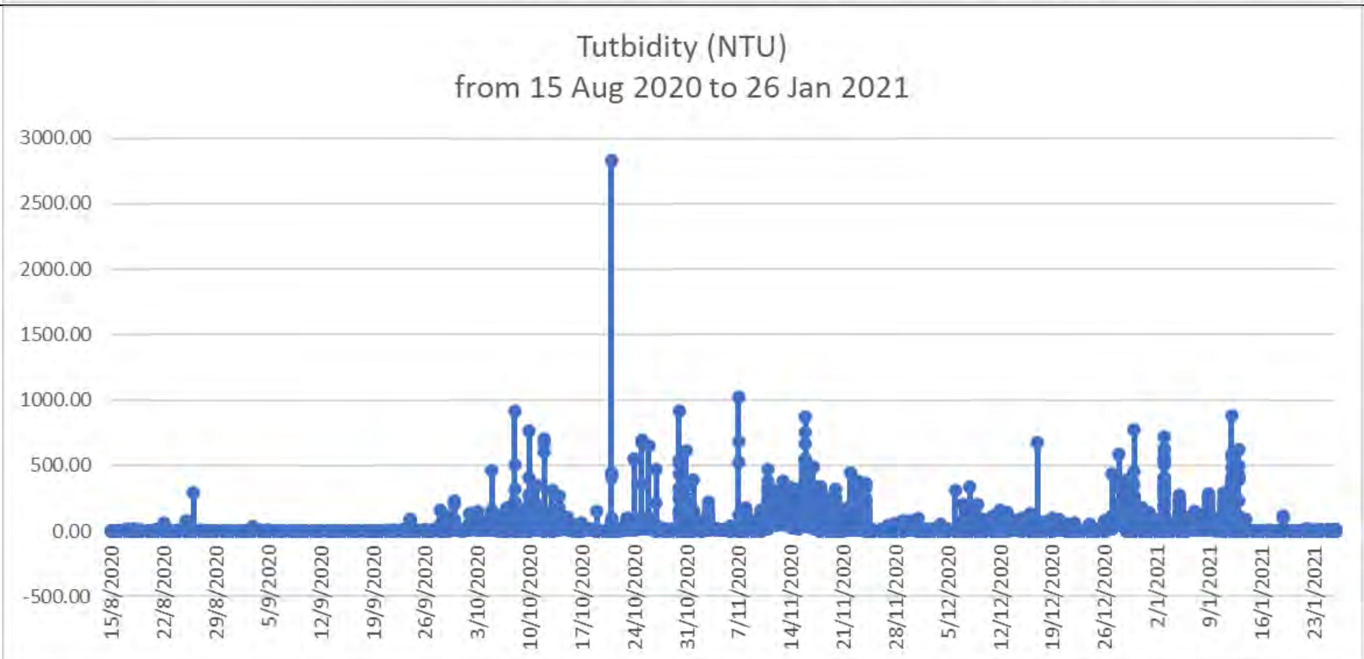


圖2F：濁度

魚病記錄

日期	魚種	病狀	處理方法	病因	獸醫／專家建議
2018 年 11 月	沙巴龍躉魚苗 (2018 年 11 月 06 日引入的批次) 花尾龍躉 (2018 年 10 月 15 日引入的批次)	11 月 12 日開始生病，11 月 14 日開始大量魚苗死亡（約每天 110 至 480 尾）。於 11 月 23 日開始, 其他花尾龍躉及沙巴龍躉都開始生病及大量死亡（約每天 50 至 536 尾）。	魚苗生病後, 於 11 月 16-19 日已分別聯絡城市大學獸醫學院及漁護署的專家一同查找原因。獸醫到現場抽取樣本到城大獸醫學院化驗。	初步相信, 因魚苗運輸到港的時間長， 在受壓的情況下降低了抵抗力， 未能適應濾水循環系統的海水而受細菌感染，引致生病及大量魚苗死亡。另外亦懷疑魚苗是先受虹彩病毒（Iridoviridae）感染， 後有繼發細菌感染（Secondary infection）。 見附件-獸醫報告。	大學獸醫建議增加每週換水次數, 以及就細菌感染情況處方藥物（Aquaflor）, 情況有改善。
2019 年 6 月	沙巴龍躉魚苗 (2019 年 6 月 4 日引入的批次)	發現魚鰓有寄生蟲（絛蟲及吸蟲）	聯絡漁護署的專家到場抽取樣本化驗。。	因發電機損壞，水質不穩定以致魚苗生病	電力恢復後，海水經過濾消毒，水質比較穩定，加上服用漁護署提議的驅蟲藥 (Hadaclean®, Bayer, 主要成分 Praziquantel 吡喹酮，專門治療絛蟲及吸蟲)，魚苗情況好轉。 在長期測試後，就育苗系統的魚缸排水方向及速度受海浪及水平面影響，已作出下列改善工作: 改善方法(一): 第二層的運水喉直徑由原有的 25mm 改大至 50mm，每個魚缸的進

					水及排水口由原設計的一組增加至兩組，以增加水體流量； 改善方法(二): 在生物過濾後的儲水缸加裝增氧機(oxygen concentrator)配合注射器(venturi injector) 使用，以增加水體含氧量； 改善方法(三): 加裝溴氧機，在蛋白分離器的注射器注入適量溴氧加強蛋白分離器帶走水中沉積物的過程及增加消毒功能； 改善方法(四): 加裝紫外光燈及改善紫外光燈的位置，連接到生物過濾後的儲水缸，經消毒後才供水至第二及三層的魚缸； 改善方法(五): 將系統的運行方法由密敝式改為半開放式，以減低有害氮化物的積聚。

					另外城大獸醫亦建議以下方法： 減少系統中魚苗的數量。
2019 年 11 月	沙巴龍躉幼魚 (2019 年 6 月 4 日引入的批次)	2019 年 10 月，幼魚轉放網箱。2019 年 11 月，水溫逐漸降低，幼魚食慾不佳，發現口內有魚蝨。	聯絡城市大學獸醫到現抽取樣本化驗。	2019 年 11 月，水溫逐漸降低，幼魚未能適應網箱環境，幼魚食慾不佳，抵抗力較弱，容易受寄生蟲侵襲。	將魚口內的魚蝨捉走。在網箱中放置水袋，使用經過濾及消毒的海水隔離飼養生病幼魚，待情況好轉後才放回海中網箱。

附件-獸醫報告

Case 2018 – 27

Nov 20, 2018

HX: three groups of fish (two hybrid grouper and one giant grouper) transferred to RAS site on floating barge and one group of hybrid grouper starting to die within 1 week of transfer. Mortality increasing fish have skin ulcers

Findings :

- Water quality issues
- Missing swimbladder (genetic issue)
- *Vibrio harveyi* Infection in fish (kidney culture)
- Histology suggest viral infection (confirmed by AFCD iridovirus)
- Poor body condition in hybrid grouper

Recommendation

- Water exchanges and daily monitoring of ammonia, nitrite and nitrate.
- Treat the bacterial disease with antibiotic (see prescription)
- Reduce densities
- Remove dead fish daily
- After the mortality is over meet with CityU veterinarians and AFCD to discuss prevention strategy for future

CITYU VETERINARY DIAGNOSTIC LABORATORY

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CityU VDL Order No: C18006230
Report To: [redacted] f Department of Infectious Diseases and Public Health, City University of Hong Kong 5/F, Block 1, To Yuen Building, 31 To Yuen Street City University of Hong Kong, Hong Kong
Ordered by: [redacted]
Phone [redacted]

Sample Collection Date&Time: 19/11/2018 14:14
Date Received by CityU VDL: 19/11/2018 14:14
Owner Name: [redacted]
Animal Name: Sabah Grouper
Species: Fish
Breed: Grouper
Sex: Unknown
Date of Birth: 01/09/2018
Client Ref #: C2018-27

Report

Biopsy Report C18006230

History and Gross pathology : 19.11.2018

Three batches of fish. Salt water fish in recirculating system.

Fish were received dead, grouped in plastic bags, exhibiting mild to moderate autolytic change.

All fish:

Skin scrapes revealed no parasites.

Gill clips revealed no parasites.

Intact swim bladders were rarely seen in any of the batches of fish examined (possibly a congenital problem – fish swim on bottom of tanks, and more susceptible to picking up infections).

Group A. Hybrid grouper. Fish were moderately to markedly thin, emaciated, often with a slightly kinked profile. Little abdominal fat. Mortality 200/6000 fish per day. These fish have been present in this farm for 2 weeks.

- Group A1. 10 fish, average of 8.4 grams each. Many fish had irregular, randomly scattered skin ulcerations, varying in size from 2 x 2 to 7 x 5 mm in size. Occasional fish in this batch had moderately swollen kidneys. One fish to include kidney and two sections of skin were collected for histology.
- Group A2. 6 fish, each approximately 8 grams each. All fish were moderately autolyzed and moderately/markedly thin.
- Group A3. 10 fish, average 7.4 grams each. Many fish had moderately to markedly enlarged spleens, which were deep red in colour. Two representative spleens were collected for histology. All fish were moderately thin.

Group B. Giant grouper. Mortality < 10/5000 fish per day. (Acceptable level of daily mortality). Fish arrived 22th of October.

Seven fish, average 6.7 grams each. Fish often had superficial abrasions over head – presumed secondary to cannibalism associated with feeding. Fish had food in stomach. Moderately thin body condition. Small, normal spleens (one spleen collected for comparison for group A fish).

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Group C. Hybrid grouper. 8 fish, average 9.6 grams each. Mortality 30/6000 fish per day. Fish arrived 29th October. One fish had a single skin ulcer along caudal ventrum (18 x 3 mm). Occasional fish had mildly enlarged spleens (3 x 1 mm). One spleen was collected for histology. Fish had a slight greenish tinge to skin over body.

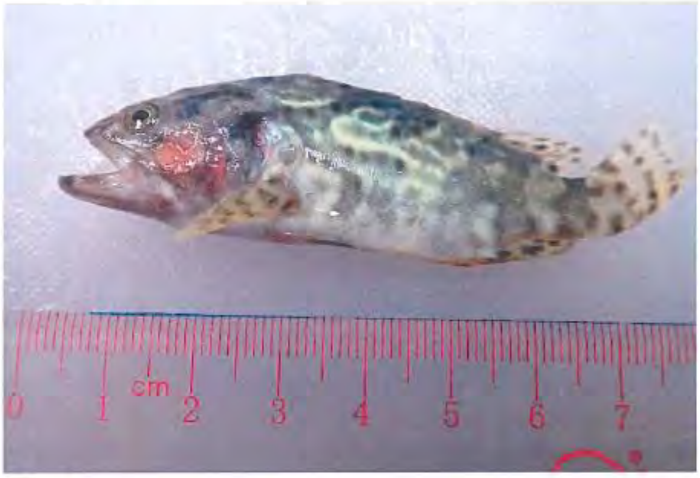

Figure A. Group A. Image of fish with skin ulcerations and kinked body profile.

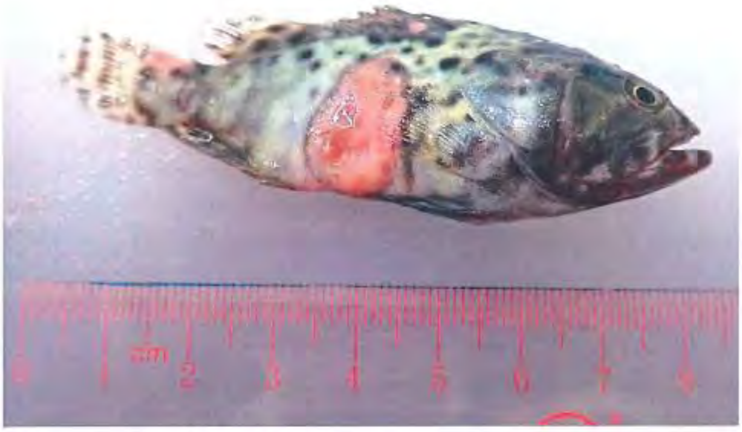

Figure B. Group A. Multiple, variably sized skin ulcers on body.

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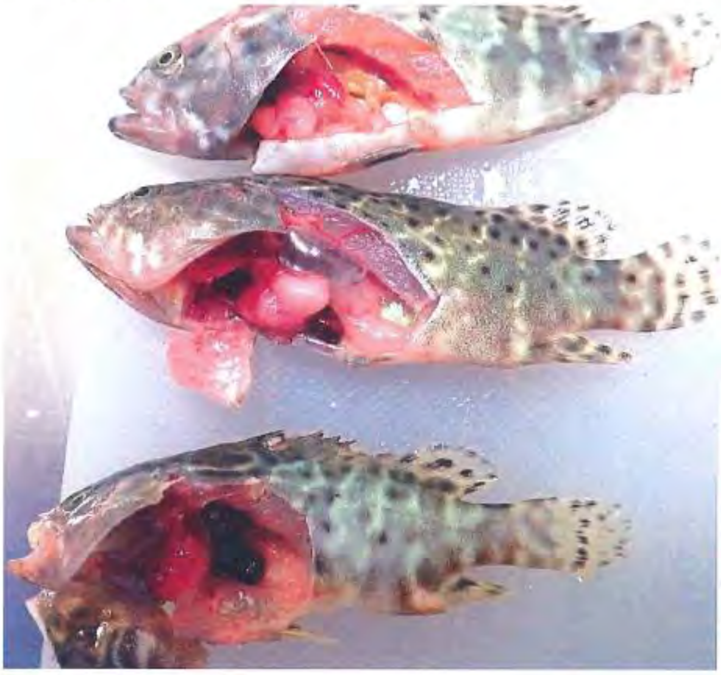

Figure C. Group A3. Enlarged spleens seen in opened coelomic cavity.

Figure D. Group B. Superficial skin abrasions around head – presumably secondary to cannibalistic behaviour.

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Figure E. Group C. The bottom fish has a focal ulcer along the caudoventral aspect of the body.

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Microscopic Description:

Group A:

Transverse sections through one fish from group A1 had low numbers of scattered, necrotizing granulomas with small, gram negative bacterial rods within the centres, within the spleen and liver (Figure 1).

Ulcerative skin lesions collected from two fish (group A1 and A3) extended deeply into muscle tissues, which were severely necrotic, associated with a surface oriented inflammatory reaction (This tissue was autolyzed, so the identity of the inflammatory cells was unable to be ascertained). Gram negative short and long filamentous bacterial rods were seen within surface necrotic tissues (Figure 2). Much of the skeletal muscle within transverse sections of these 2 fish had extensive, multifocal areas of acute necrosis with fragmentation of muscle fibres, accompanied by minimal inflammation (Figure 3).

Two fish from this group had portions of pyloric caecae collected. There were frequent cells within the mucosa (either epithelial cells and/or lamina proprial cells) with large, intranuclear material, often associated with chromatin margination. This material stained moderately pink with PAS. There was mild inflammation with granulocytes and fewer mononuclear cells within the underlying lamina propria. (Figures 4 and 5).

The fish from group A1 with the enlarged kidney showed severe, multifocal necrotizing nephritis with low numbers of tiny, intralesional, gram negative bacterial rods (Figure 6).

Two enlarged spleens (measuring 8 x 4 mm and 7 x 3 mm) from two fish in this group were examined. One spleen contained multiple foci of histiocytic cells, often containing abundant intracytoplasmic, blue/granular bodies, approximately 1-2 um, which were weakly pink to blue on PAS. (Figures 7 to 9). These structures are suggestive of protozoa.

The second spleen had a few scattered loose clusters of large megalocytic cells, containing large, intranuclear blue material, with chromatin margination. These cells were occasionally embedded in thin strands of pink collagen. There were irregular areas of lytic necrosis within the parenchyma. (Figure 10).

Sections of gills, stomach, heart and spinal cord, did not show any significant changes.

Group B:

Section of spleen did not reveal any abnormalities.

Group C.

A moderately enlarged spleen, which measured 6 x 2 mm had moderate diffuse congestion and moderate expansion of histiocytic cells in the parenchyma, consistent with reactive hyperplasia.

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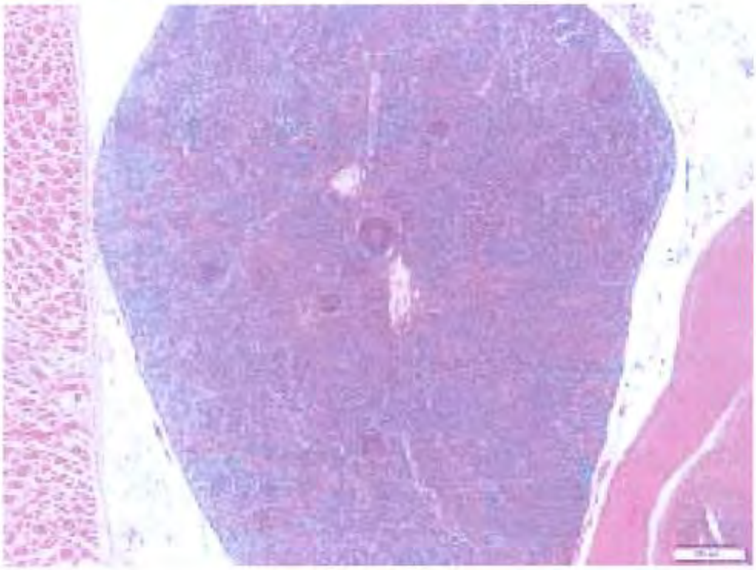

Figure 1. Group A1. Multifocal splenic granulomas (x 4) H and E.

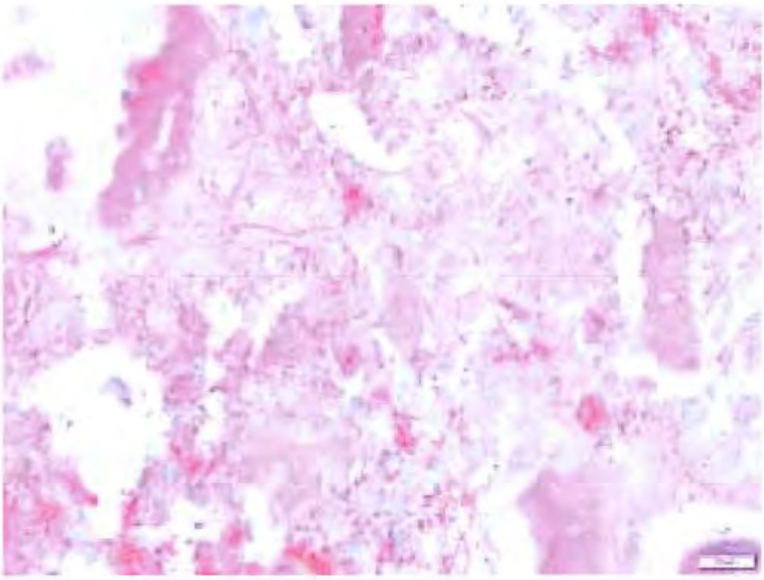

Figure 2. Group A1. Necrotic dermatitis with gram negative bacterial rods (x100), gram stain.

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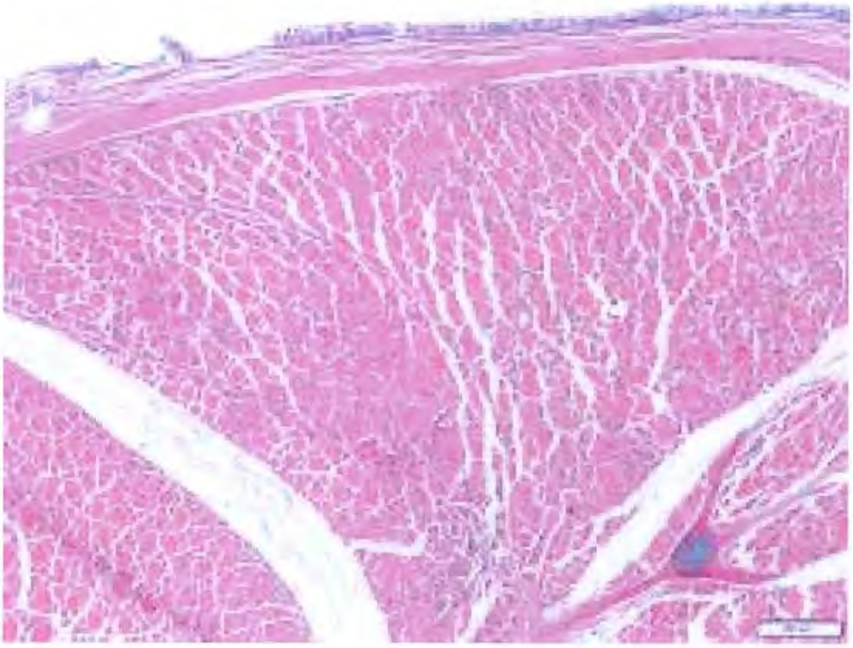

Figure 3: Group A1. Multifocal acute skeletal muscle necrosis (x4). H and E.

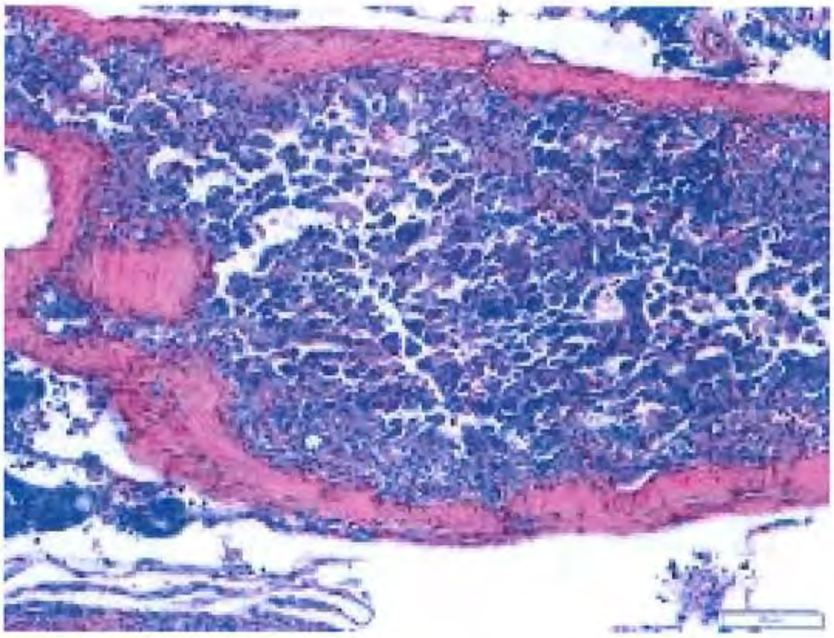

Figure 4: Group A. Pyloric caecum: Numerous intraepithelial/intranuclear blue/purple material within the mucosa/lamina propria x 20, H and E.

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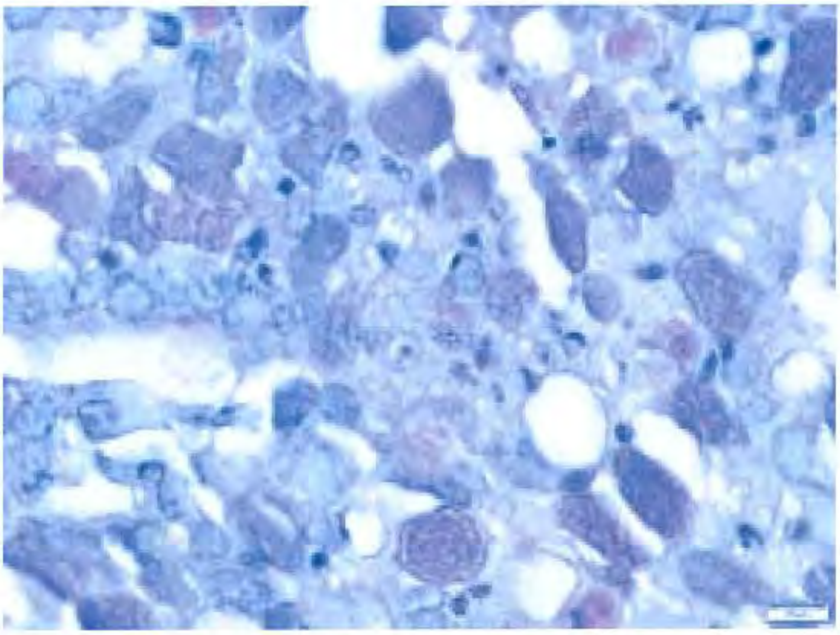

Figure 5: Group A. Pyloric caecum: Intranuclear PAS positive inclusions with nuclear chromatin margination (x100), PAS.

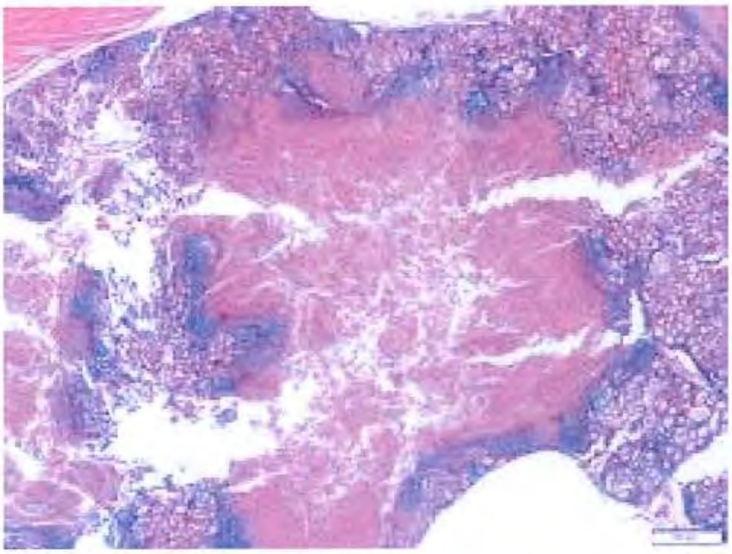

Figure 6: Group A1. Kidney with extensive necrosis of parenchyma x 4, H and E.

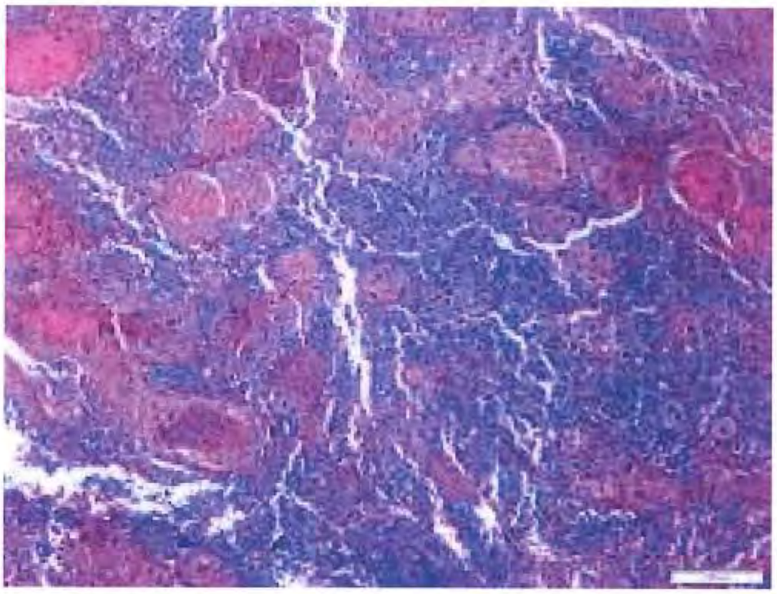

Figure 7: Group A1. Spleen with clusters of histiocytic cells with blue cytoplasmic material. X 10, H and E.

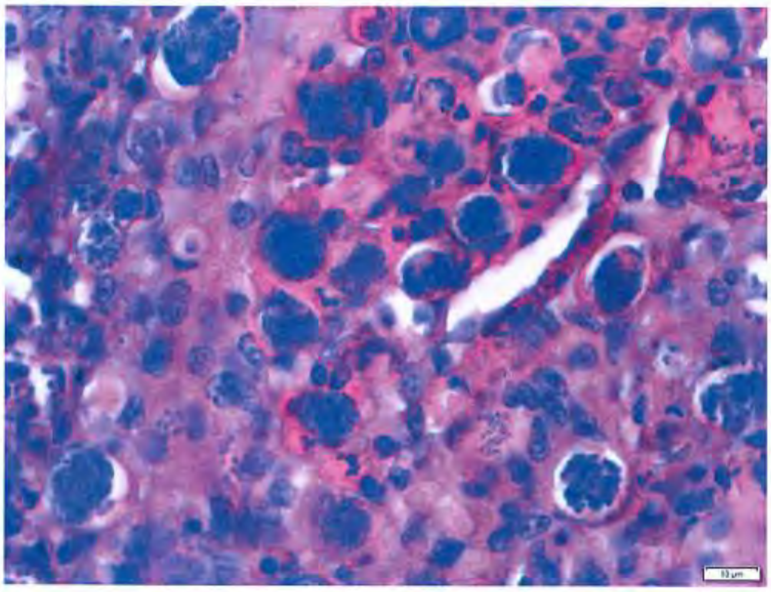

Figure 8: Group A1. Spleen with clusters of histiocytes with blue cytoplasmic granular material. X 100, H and E.

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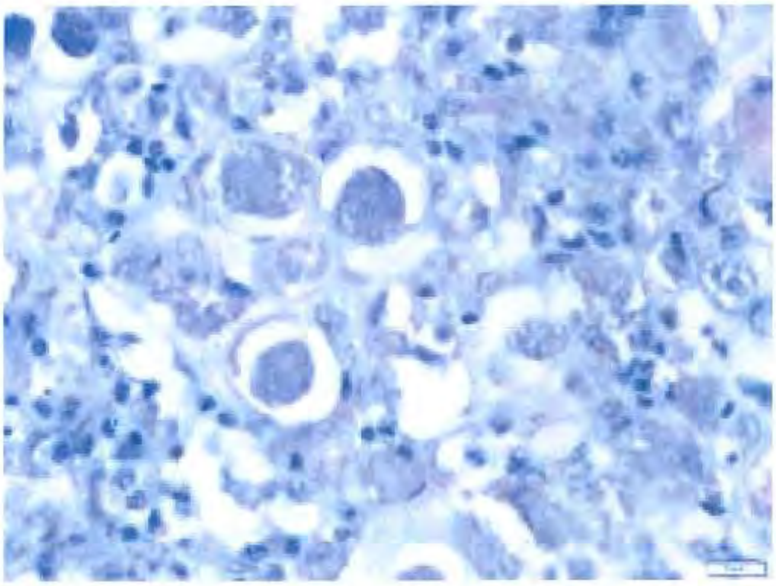

Figure 9: Group A1. Spleen with clusters of histiocytes with blue to weakly pink cytoplasmic granular material. X 100, PAS.

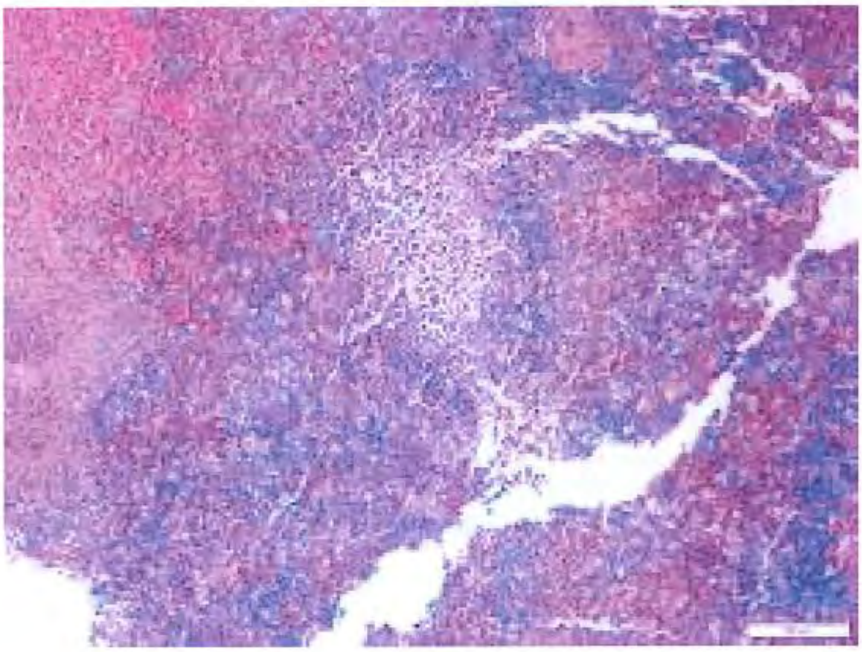

Figure 10. Spleen with intranuclear inclusions within megalocytic cells x 4, H and E.

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Morphological Diagnosis:

All fish:

- Moderate to marked emaciation
- Ruptured swim bladders.

Group A and C.

- Multifocal necrotizing dermatomyositis with systemic spread to liver, spleen and kidney with intralesional, gram negative bacterial rods.
- Pyloric caecae – suspected intranuclear inclusions within pyloric mucosal epithelium/lamina proprial cells.
- Moderately to marked splenomegaly – Groups A3 and C.
    - One spleen: Splenic granulomas with intracytoplasmic granular inclusions – possible protozoal infection.
    - One spleen: Splenic intranuclear inclusions within megalocytic cells.

Group B:

Multifocal skin abrasions around the head – Group B.

Comments:

The hybrid groupers from both groups A and C exhibited severe, acute/subacute necrotizing dermatitis which extended into skeletal muscle associated with gram negative bacterial rods. A pure growth of *Vibrio harveyi* was cultured from kidney (and skin swab) from a separate fish (pers communication) from this farm, which are gram negative bacteria. This presumably culminated in systemic infection in the fish with dispersed granulomas seen in multiple organs. In addition, there are suspected intranuclear inclusions within pyloric caecal epithelium/lamina proprial cells, and in within large megalocytic cells within one section of spleen. An additional spleen contained granular intracytoplasmic material suspicious for protozoa such as Microsporidia.

Gill clips and skin scrapes (including deep scrapes of ulcerated lesions) from all fish groups did not reveal the presence of parasites.

All fish were in poor nutritional condition, but food was found in the stomachs of some fish (giant groupers).

Concern for possible genetic issues producing occasionally kinked body profiles and ruptured of swim bladders in all fish groups.

The giant groupers (group B) in this submission suffered from acute superficial skin abrasions, interpreted to represent damage by other fish, secondary to feeding behaviour. Deep skin ulcerations were not seen in this

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group of fish. This group did have absent swim bladders, but no internal lesions were seen on gross post mortem examined.

[redacted]

11/28/2018

ECOSYSTEM HEALTH AND SUSTAINABILITY, 2017
https://doi.org/10.1080/20964129.2017.1340268

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REVIEW

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The impacts of suspended mariculture on coastal zones in China and the scope for Integrated Multi-Trophic Aquaculture

Reece Wartenberg[a,b,c], Limin Feng[a,b], Jia Jun Wu[a,b], Yim Ling Mak[a,b], Leo L. Chan[a,b,d], Trevor C. Telfer[e] and Paul K. S. Lam[a,b,c]

[a]State Key Laboratory in Marine Pollution, City University of Hong Kong, Kowloon, Hong Kong SAR, China; [b]Research Centre for the Oceans and Human Health, Shenzhen Key Laboratory for Sustainable Use of Marine Biodiversity, City University of Hong Kong Shenzhen Research Institute Building, Shenzhen, Guangdong, China; [c]Department of Biology and Chemistry, City University of Hong Kong, Kowloon, Hong Kong SAR, China; [d]Department of Biomedical Sciences, City University of Hong Kong, Kowloon, Hong Kong SAR, China; [e]Institute of Aquaculture, University of Stirling, Stirling, UK

ABSTRACT

Introduction: China is responsible for more than 60% of global aquaculture production. As the frontiers of food production have expanded, the cultivation of marine organisms in coastal zones and the open ocean has grown rapidly. The dominant mariculture industry in China is suspended mariculture, which uses net cages, ropes, or other structures suspended in the water column to cultivate aquatic organisms. This systematic, quantitative review provides a clear and comprehensive account of research that has investigated the adverse impacts of suspended mariculture in China and reviews research that has applied Integrated Multi-Trophic Aquaculture (IMTA) systems for mitigating impacts. This work builds on 218 peer reviewed papers that have been published in English-language journals.
Outcomes: Eighteen impacts were identified, including chemical, ecological, physical, and socioeconomic impacts. Eighteen measures for improving suspended mariculture were recommended consisting of government department, farm management, and ecological engineering measures. IMTA was the most frequently recommended measure. The capabilities of IMTA for bioremediation and increased farm production were the most frequently studied advantages. Seven other benefits have been explored but remain understudied. The current challenges facing the expansion of commercial IMTA include limited use of new technology, limited skills development, decreasing production of low trophic-level species, biogeographic and temporal barriers, and negative system feedbacks.
Conclusion: Despite challenges, implementing commercial IMTA is a promising measure for reducing the impacts of suspended mariculture because it presents a range of secondary benefits that can improve the overall sustainability of aquaculture in the coastal zone.

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KEYWORDS
Aquaculture; bioremediation; China; impacts; Integrated Multi-Trophic Aquaculture; pollution; suspended mariculture

Introduction

In the face of climate change, economic uncertainty, and growing competition for natural resources, a pressing issue for science is how to ensure food security for more than 9 billion people by 2050. The fastest growing food production sector in recent years has been aquaculture, which has produced more fish for human consumption than capture fisheries since 2013 (FAO 2016). The largest aquaculture producer in the world is China, which is responsible for more than 60% of total world production using freshwater and marine systems (FAO 2016).

In marine aquaculture, or mariculture, one perception is that farming aquatic organisms alleviates pressure on wild stocks. In some cases, however, the opposite may be true: the farming of higher trophic-level carnivorous fish species requires large inputs of wild fish for feed. Wild fish stocks are further diminished through habitat modification, wild seed-stock collection, waste release, exotic species introductions, and the transmission of aquaculture pathogens (Naylor et al. 2000). The farming of lower trophic-level species, in contrast, is considered more environmentally sound because species such as filter feeding mollusks have a higher eco-efficiency and make a substantial net contribution to global seafood supply (Williams 1997). In China, suspended mariculture in open ocean water dominates mariculture production; however, the technique uses net cages, ropes, or other structures suspended in open ocean water and so it has been criticized because adverse impacts are freely imposed on the supporting water column. The vast scale of suspended mariculture in China implies that ecosystem-scale impacts are likely, and therefore solutions that limit or mitigate impacts are vital.

CONTACT Reece Wartenberg rwartenbe2-c@my.cityu.edu.hk State Key Laboratory in Marine Pollution, City University of Hong Kong, Tat Chee Avenue, Kowloon, Kowloon, Hong Kong SAR, China
Supplemental data for this article can be accessed here

The implementation of Integrated Multi-Trophic Aquaculture (IMTA), a form of ecological engineering in aquaculture, has been proposed to help alleviate the impacts of suspended mariculture for some time (Chopin et al. 1999; Neori et al. 2004; Troell et al. 2009). Prototypical IMTA systems aim to integrate extractive (non-fed) aquaculture species with fed species, so that the extractive species assimilate farm waste and generate a harvestable biomass that can be sold for profit. Other economic, environmental, and social benefits include increased product diversity, improved ecosystem services through improved environmental conditions, and the development of associated industries, wider employment opportunities, and social acceptance. IMTA research worldwide has shown that macroalgae, shellfish, and echinoderms can be used to assimilate dissolved nutrients, suspended particulates, and settling particulates, respectively (Chopin 2015). The implementation of IMTA is attractive conceptually, but there may be limitations: ecological engineering to enhance food production is complex and dynamic, and requires advanced skills and systems that may not be widely available yet, particularly on a commercial scale.

This paper reviews the current state of research on the impacts of suspended mariculture and the potential applications of IMTA in China. A systematic, quantitative assessment of the literature was conducted to examine impacts, collate recommendations for mitigating impacts, and identify the scope for, and challenges facing, IMTA in China. Details of the methodology employed in the literature search are available in Appendix S1. Chinese aquaculture production data were extracted from the China Fishery Statistics Yearbooks published annually by the Ministry of Agriculture (MoA) of the People's Republic of China (MOA 1981–2016).

Mariculture in China

China has consistently produced more than 60% of the world's aquaculture products for the past two decades. Recent projections suggest that this proportion will be maintained through 2025 (FAO 2016). In 2015, China farmed 49.37 million tons (RMB 828 billion, ~US$120 billion) of aquatic products, of which 18.75 million tons (38% production, 35% value) was produced using mariculture (MOA 2016).

At present, freshwater aquaculture may contribute the bulk of aquaculture production in China, but the practice adds pressure to China's already overexploited freshwater resources. In northern China, there has been an increase in droughts that is compounding a pre-existing uneven distribution of fresh water across the country. Agriculture, in particular, has suffered heavily (Ye et al. 2016). Additionally, freshwater aquaculture in China produces less biomass per hectare than mariculture (Figure 1). It is therefore unlikely that production from freshwater aquaculture will continue to meet the growing demand for aquatic products over the long term, and so focusing efforts on developing sustainable mariculture is favorable.

Mariculture production in 2015 was made up of predominantly low trophic-level species; 13.58 million tons of mollusks, 2.01 million tons of macroalgae, 1.43 million tons of crustaceans, 1.36 million tons of finfish, 0.21 million tons of echinoderms, and 0.07 million tons of other aquatic species such as jellyfish (MOA 2016). In 2014, 12 million tons of bivalve mollusks were farmed – five times higher than those produced in the rest of the world (FAO 2016).

Mariculture production is unevenly distributed along China's 18,593 km coastline which covers nine coastal provinces. The bulk of mariculture production comes from Liaoning, Shandong, Fujian, and Guangdong, which together represent 61% of the

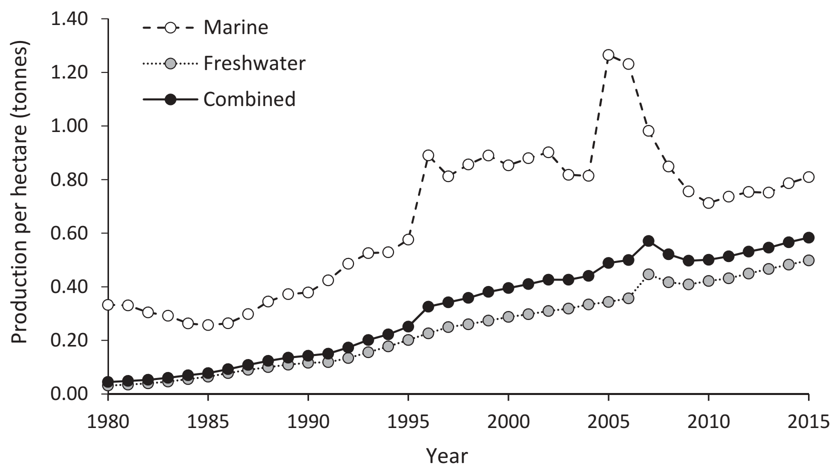

Figure 1. Annual production per hectare (tons) from freshwater and marine aquaculture in China from 1980 to 2015. Data were extracted from the China Fishery Statistics Yearbooks (MOA 1981–2016).

coastline but produced approximately 80% of marine aquatic products in 2015 (Figure 2) (MOA 2016).

Four mariculture systems are dominant (Figure 3). Recirculating aquaculture systems and marine ponds are land-based systems that accounted for 0.19 million tons (1.01%) and 2.35 million tons (12.53%) of production in 2015 (Figure 3). Sea ranching and suspended mariculture can be open-water, coastal or offshore, systems. Sea ranching, or bottom culture, does not require physical aquaculture structures and

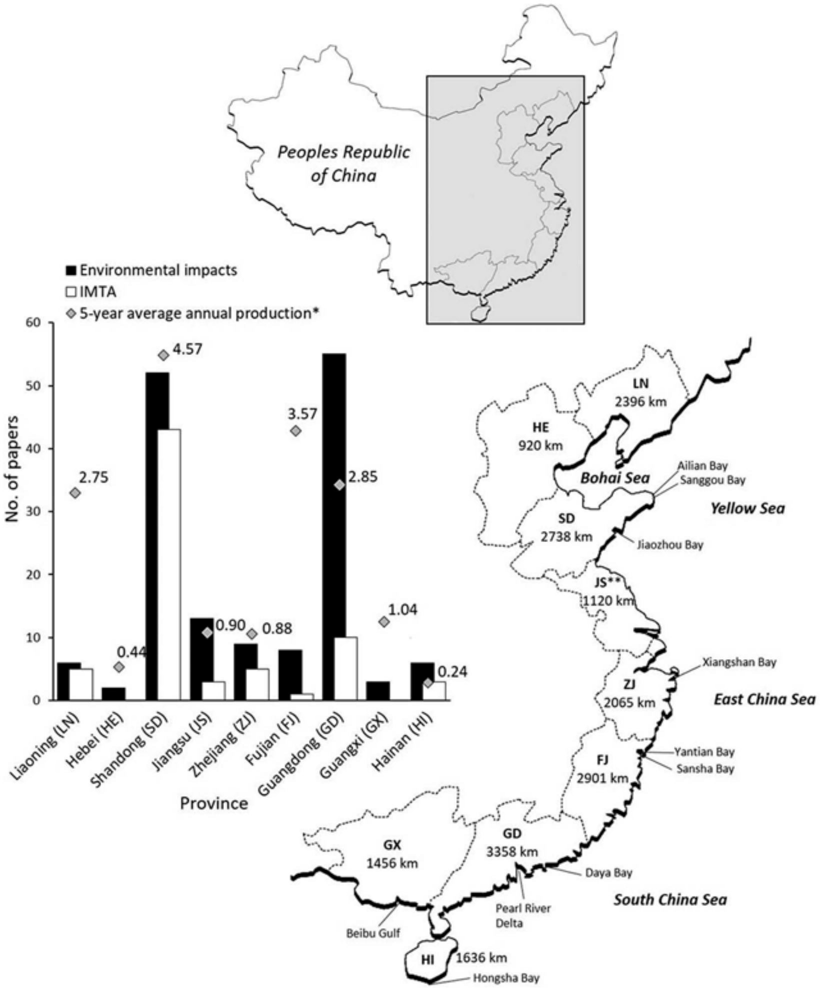

Figure 2. Map of China showing the location of the nine coastal provinces and the lengths of their coastlines. The inset graph shows the total number of publications from each province that have investigated the environmental impacts of suspended aquaculture or Integrated Multi-Trophic Aquaculture. Provinces in the inset graph are listed from north to south. * The 5-year average annual mariculture production ($\times 10^6$ tons) was extracted from the China Fishery Statistics Yearbooks (MOA 1981–2016). **The coastline length of Jiangsu includes the 196 km coast of Shanghai.

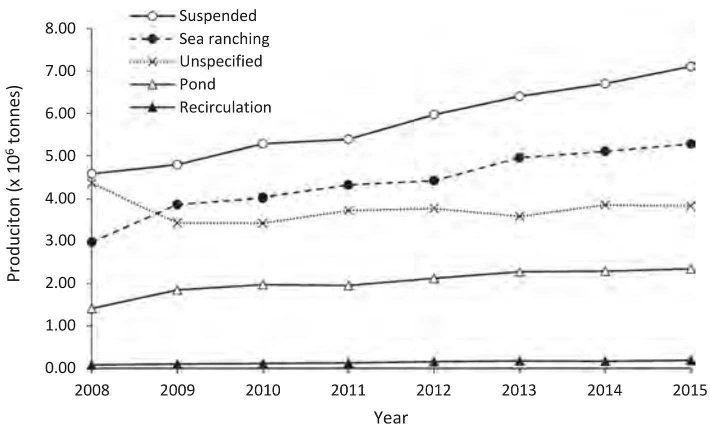

Figure 3. Total annual production from the different mariculture techniques practiced in China from 2008 to 2015. Data were extracted from the China Fishery Statistics Yearbooks (MOA 2009–2016).

is practiced by stocking hatchery-reared organisms in the open sea for growout and future harvest (e.g., Wang et al. 2017). Suspended mariculture systems require moorings and rigging such that culture organisms can be suspended in the water column. There are two modes of suspended mariculture: longline culture of macroalgae, bivalves or other mollusks, and sea cage, or "fish raft," culture of fed species. Fish raft systems are sited and moored using methods similar to longline systems but they incorporate floating platforms to facilitate husbandry activities such as feeding and net-cleaning. The surface area of individual fish cages in China is typically small, under 25 m^2 each. Sea ranching and suspended mariculture accounted for 5.28 million tons (28.12%) and 7.11 million tons (37.89%) of total mariculture production in 2015 (Figure 3). Approximately 3.83 million tons (20.43%) of Chinese mariculture production came from unidentified sources that may include the above techniques, as well as pen culture (e.g., Beveridge 1984) or other unspecified techniques. Suspended mariculture therefore represents the largest contributor to Chinese mariculture production and is the focus of the present review (Figure 3).

Results

The environmental impacts of suspended mariculture in Chinese waters have been examined in at least 161 papers since 1994 (Appendix S2). The various applications of IMTA in China have been assessed in at least 73 papers since 1996 (Appendix S3). Fifteen (7%) of the papers were relevant to both topics. Most research has been conducted in Shandong and Guangdong (Figure 2). It is conceivable that 2010 represents the start of modern research on these topics because 155 (71%) of the papers were published between 2010 and 2017 (Figure 4).

The environmental impacts of suspended mariculture

Suspended mariculture in China was linked to 18 environmental impacts. Impacts from all trophic levels were characterized as eight chemical, five ecological, two physical, and two socioeconomic impacts (Figure 5).

Trophic-level impacts

There has been a strong focus on studies investigating the impacts of finfish (86 papers) and shellfish (82 papers) mariculture, while the impacts of macroalgal cultivation have been studied less frequently (42 papers). The impacts of echinoderm culture were studied by five papers that were relevant to this review, but the echinoderms were cultured in pond or sea ranching systems rather than in suspended systems.

Chemical impacts

Chemical impacts included pollution from organic and inorganic nutrients, and pollution from anthropogenic sources including toxic compounds, pharmaceuticals, and metals. Together these can change the composition of sediment, contribute to eutrophication, or cause hypoxic or anoxic conditions. The most frequently discussed and demonstrated chemical and overall impact caused by suspended mariculture in China is the release of inorganic waste (Figure 5). Although eutrophication was frequently discussed in the literature (46 papers), fewer studies proceeded to demonstrate the contribution of suspended mariculture to eutrophication (13 papers).

Ecological impacts

Ecological impacts have included changes to surrounding ecological communities, the induction of algal blooms, the transmission of pathogens form

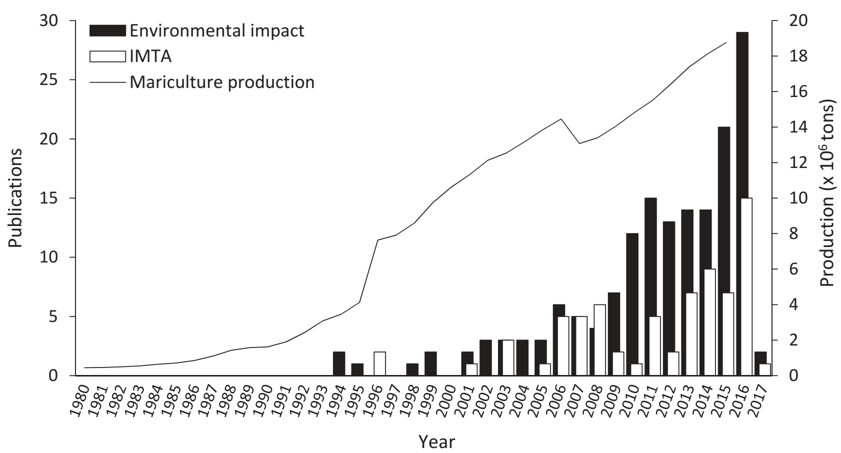

Figure 4. The number, per year, of published papers that have investigated the impact of suspended aquaculture (161 papers) or the applications of Integrated Multi-Trophic Aquaculture (72 papers) in Chinese waters from 1980 to 2015. The solid line represents the total annual mariculture production for the same period.

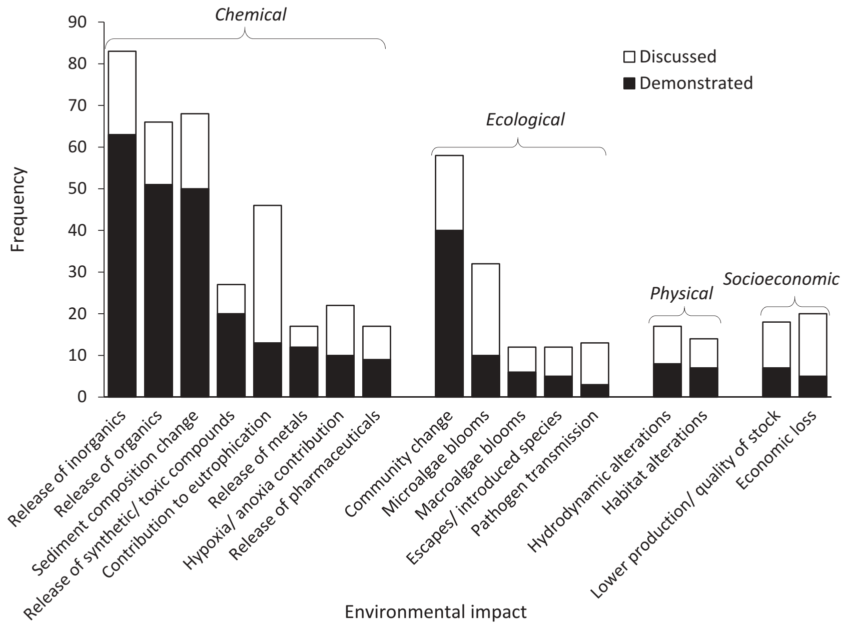

Figure 5. Frequency of the environmental impacts either discussed or demonstrated by at least 161 papers that have studied the impacts of suspended mariculture in Chinese coastal waters since 1994.

cultivated stock to wild communities, and the escape of cultivated stock that can disrupt local populations. Changes to community structure were the most frequently studied ecological impact (Figure 5).

Physical and socioeconomic impacts

The physical and socioeconomic impacts of suspended aquaculture remain relatively understudied. Initial research has shown that physical impacts can include alterations to hydrodynamics and habitat, while socioeconomic impacts can include decreased productivity, decreased stock quality, and economic loss (Figure 5).

Recommendations to improve suspended mariculture

Ninety-two papers that investigated the environmental impacts of suspended mariculture made explicit recommendations for improvement. Eighteen recommendations were categorized as either “farm management” (74 papers, 42%), “government management” (47 papers, 27%), or “ecological engineering” (55 papers, 31%) measures (Figure 6). The most frequently recommended measure in each category, respectively, was to site farms carefully and enforce appropriate stocking densities, improve policy and regulations, and implement IMTA (Figure 6). IMTA was the most frequently recommended measure overall (25 papers).

The benefits of IMTA in China

In China, 72 papers show nine potential benefits of IMTA. Forty-eight papers explicitly recommended its implementation. The potential benefits of bioremediation and/or biomitigation, and the possibility of increased farm production are most frequently demonstrated (Figure 7). Seven other benefits are discussed and/or demonstrated: improved ecosystem function, increased financial return, improved sustainability, decreased stock mortality, increased product quality, potential for pathogen control, and improved public opinion and social benefits. The possibility that IMTA could improve farm financial return was discussed in 22 papers but only 5 papers proceeded to demonstrate a positive financial impact.

Discussion

Suspended mariculture environment

China’s coastline spans 23 degrees of latitude (17–40° N) and 16 degrees of longitude (108–124.5° E) (Xiao et al. 2007) and is therefore characterized by a variety of climates, morphological features, biodiversity, and anthropogenic pressure. The high population density of China’s coastal provinces strain the marine environment (Ding, Ge, and Casey 2014; Williams et al. 2016). All major coastal water bodies are impacted by human activities (Xiao et al. 2007). Suspended mariculture sites face pollution from terrestrial runoff, river discharge, and submarine groundwater discharge (He et al. 2008). Further challenges include habitat alterations and pollution from large marine industries including shipping, pond aquaculture, and contaminants from atmospheric sources (Ding, Ge, and Casey 2014; Hou et al. 2016).

Good shelter and wave attenuation are the primary criteria for the development of mariculture in China

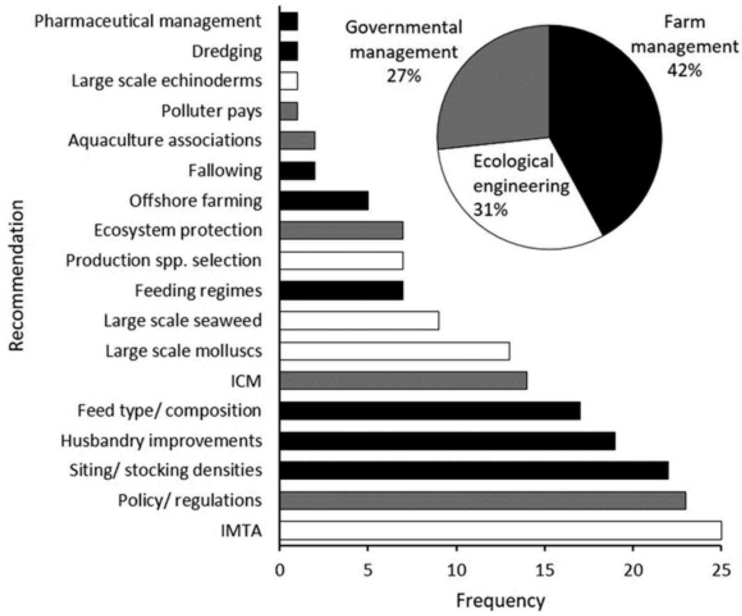

Figure 6. Frequency of the recommendations made in 92 papers for improving the impact of suspended mariculture in Chinese waters. ICM, Integrated Coastal Management; IMTA, Integrated Multi-Trophic Aquaculture. The inset pie chart shows the proportion of recommendations falling into the three relevant management strategies.

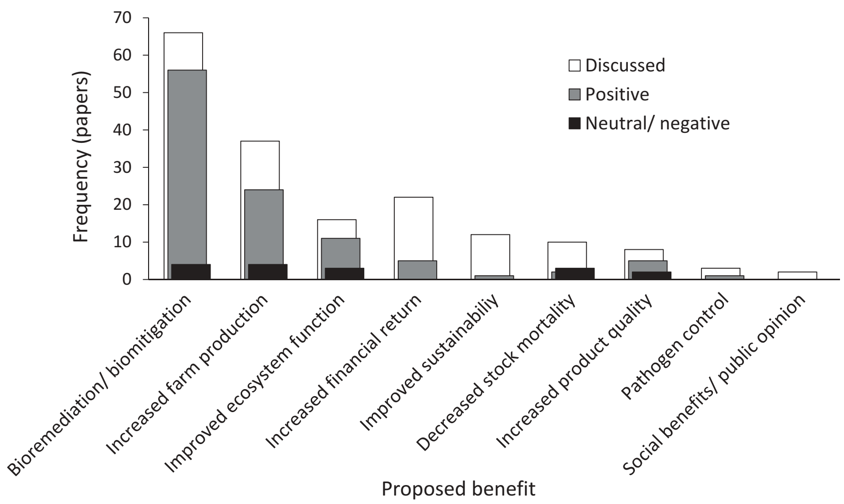

Figure 7. Frequency of the proposed benefits of Integrated Multi-Trophic Aquaculture (IMTA) from 73 papers involving studies of IMTA in Chinese coastal waters. Proposed benefits were either "discussed" or "demonstrated." Studies that demonstrated an effect found a "positive" or "neutral/negative" effect.

(Ma et al. 2015). Shallow seas with depths up to 10 m cover 10 million ha (Xie et al. 2013). The majority of suspended mariculture therefore occurs in the numerous semi-enclosed bays, on mud flats and in shallow seas (Cao et al. 2007). Wang (1993) estimated that 1.3 million hectares of inshore area are suitable for mariculture. Xiao et al. (2007) identified 50 major coastal bays, most of which have a >400 km^2 surface area and already support suspended mariculture activities.

Bays and islets are often characterized by slow water exchange and so pollutants can accumulate readily in the vicinity of aquaculture operations (Wu et al. 1999; Lee, Choi, and Arega 2003). Accumulation of effluent is dangerous because in the shallow inshore region the resuspension of toxic substances in adverse weather occurs easily (Wong and Cheung 2001; Qi et al. 2013). As an alternative, the potential for expanding production from offshore aquaculture has been proposed but offshore systems remain underdeveloped and understudied (Qi et al. 2013). Production from circular fish cages sited offshore in China accounted for only 0.56% of total aquaculture production in 2015 (MOA 2016). Understanding the impacts of the environment on aquaculture, and the impacts of aquaculture on the environment, are necessary for achieving sustainable aquaculture (Han, Keesing, and Liu 2016).

The environmental impacts of suspended mariculture

While aquaculture has been practiced in China for thousands of years, suspended mariculture started only recently but has expanded rapidly. Suspended fish cage mariculture originated in Hong Kong in the 1960s (Lai and Yu 1995). Details on production from suspended mariculture in China in the early years have not been published, but it is known that the mariculture industry boomed from the early 1970s. Production increased from 0.01 million tons in 1950, to 0.18 million tons in 1970 and then to 18.75 million tons in 2015 (Figure 4) (Tseng 1993; Zhong and Power 1997; MOA 2016). Suspended mariculture is now the biggest contributor to Chinese mariculture production (Figure 3). Growth of suspended mariculture has been driven largely by shellfish and macroalgal culture in shallow coastal waters (Tang, Zhang, and Fang 2011), but the rapid increase of mariculture production has caused a rapid increase in environmental impacts.

Trophic-level impacts

It is well recognized that the impacts of suspended aquaculture are dependent on the culture species, culture method, culture density, feed type, general husbandry practices, and site-specific characteristics including local and regional hydrodynamics (Wu 1995; Gao et al. 2005). These factors vary widely in China because of the diversity of culture organisms, culture methods, environments, and climates. Despite relatively low finfish production (7.2% by volume in 2015, MOA 2016), the high frequency of studies that have investigated the impacts of suspended finfish culture is probably because finfish have a substantially higher value per kilogram and require feed input that intensifies impacts. The research attention on the impacts of shellfish is probably because the production of shellfish vastly outweighs all other groups in China (72.4% by volume in 2015, MOA 2016) and because the cultivation of shellfish presents a paradox; on the one hand shellfish may help to assimilate suspended particulates but on the other hand shellfish may only partially assimilate particulates and can produce large volumes of psuedofeces and feces that have a high settling velocity and can pollute benthic habitats (Ren and Zhang 2016). Macroalgal culture is reputed as an environmentally sound form of mariculture because of its extractive properties that can help to alleviate eutrophication and restore ecosystem services (Edwards 2015); however, impacts from suspended macroalgal culture are plausible and include the inhibition of water flow and light penetration, and the deposition of large amounts of tissue from breakage and drop-off (Zhang et al. 2012; Zhou 2012). The potential for cultivating echinoderms in suspended systems remains experimental and so the impacts caused by suspended echinoderms have not been investigated (e.g., Yu et al. 2012). This review grouped the impacts from all trophic levels as either chemical, ecological, physical, or socioeconomic (Figure 5).

Chemical impacts

Common inorganic substances include nitrogen, phosphorous, and sulfur compounds such as ammonia, nitrate, phosphate, sulfate, and pyrite-S (Cai et al. 2016; Duan et al. 2016; Kang, Liu, and Ning 2016). Organic waste includes fish feed and feces, urea, dead and decaying culture organisms, and methane (Leung, Chu, and Wu 1999; Hou et al. 2016). When inorganic and organic substances settle, changes in sediment composition can result. Settling biodeposits, synthetic compounds, or metals are commonly recorded from sediment in aquaculture zones (Wang et al. 2013; Wang et al. 2014a; Ren and Zhang 2016). The natural chemical reactions for processing waste from fish farms can give rise to hypoxic or anoxic sediment and water bodies (Zhang, Huang, and Huang 2013; Kang, Liu, and Ning 2016). Chemical impacts from suspended aquaculture are generally caused by the continuous or pulse release of waste substances associated with normal husbandry activities (Yang et al. 2006; Xu et al. 2011).

When the release of nutrients is substantial, eutrophic conditions can occur (Cao et al. 2007; Xu et al. 2008). The disparity between papers that discuss eutrophication as an impact from suspended mariculture and papers that demonstrate it is probably because of the difficulty in identifying the source of nutrients in open coastal systems impacted by several human activities (Figure 5). Common sources of nutrients in China's waters include discharge from rivers, discharge from industrial outlets, submarine groundwater discharge, coastal pond aquaculture effluent, wastewater from shipping ports, urban runoff and untreated sewage, pollutants from large-scale sea ranching and pond aquaculture operations, and waste from suspended mariculture. The combined result can cause nutrient concentrations multiple times higher than natural levels and so many coastal areas in China are eutrophic (Zhou et al. 2006c; He et al. 2008).

The release of synthetic compounds has included polycyclic aromatic hydrocarbons that have been linked to the operation of boats supporting aquaculture infrastructure (Klumpp et al. 2002; Yu et al. 2012). Various persistent halogenated compounds (PHCs), pesticides such as DDT (dichlorodiphenyltrichloroethane), and pharmaceuticals have originated in feed (Yu et al. 2011b; Chen et al. 2015; Fang, Bao and Zeng 2016). The release of pharmaceuticals from aquaculture in China has been reviewed previously and, in the context of coastal aquaculture, has included high levels of sulfonamides that can cause the occurrence of antibiotic-resistant genes (He et al. 2016). Higher concentration of metals such as Zn, Ni, Cu, Cr, Pb, and Ca has been linked to antifouling paints on aquaculture infrastructure and the use of low-quality feeds (Gu et al. 2014; Liang et al. 2016). If chemical impacts are substantial, ecological impacts can occur.

Ecological impacts

Research in China has shown that suspended aquaculture systems can cause changes to surrounding ecological communities by significantly altering benthic, microbial, planktonic, and fish community dynamics (e.g., Jiang et al. 2012; Han et al. 2013a; Lu et al. 2015; Zhao et al. 2016).

Two other widely publicized ecological impacts are micro- and macro-algae blooms, which proliferate and thrive in eutrophic environments. Harmful algal blooms (HABs), comprising microalgae, have caused major stock and economic loss to the aquaculture industry and have also caused large-scale mortality of wild populations for decades (Lai and Yu 1995). The frequency and extent of HABs has been increasing in China (Wang et al. 2008; Lu et al. 2014a). Based on long-term data from Hong Kong, Lee (2016) showed a significant positive correlation between the intensity of coastal mariculture and the occurrence of HABs. Macroalgal blooms have started to occur more recently and have been reported in the northern East China Sea and Yellow Sea since 2007 (Keesing et al. 2011). These seaweed blooms have been shown to originate from open water suspended *Porphyra* culture systems and have spanned more than 40,000 km^2 in some instances. Bloom-forming species including *Ulva* and *Enteromorpha*spp. have caused major economic loss by inundating waterways and beaches, and have caused widespread asphyxiation of organisms when the blooms biodegrade (Liu et al. 2009; Liu et al. 2013). A third bloom type, jellyfish blooms, has also been linked to the expansion of suspended mariculture because husbandry infrastructure provides substrate for larval settlement and husbandry activities provide nutrients for proliferation (Dong, Liu, and Keesing 2010).

Further ecological impacts are the transmission of pathogens and the introduction of escaped culture organisms that can include invasive species. Pathogens tend to flourish in intensive aquaculture because culture organisms are stocked at high density, are easily stressed, and so are more susceptible to infection (Pang et al. 2015; Liu et al. 2016). In cultured grouper, it was shown that parasitic gill monogeneans have a higher species richness and diversity in suspended mariculture systems compared to grouper harvested from the wild (Luo and Yang 2012). It has been hypothesized that pathogens can be transmitted to natural populations either by direct transfer or through escaped culture organisms as vectors (Bondad-Reantaso et al. 2005); however in China, this remains to be demonstrated in suspended mariculture. Lin et al. (2015) reviewed the introduction of non-native species for use in aquaculture in China, but the impact of escaped/released organisms from suspended mariculture requires further investigation. Escaped indigenous species can dilute the genetic diversity of natural populations while introduced species can lead to successful ecological invasions (Wang et al. 2007a; Wang et al. 2014b).

One ecological impact that remains unstudied is the release of macrowaste (garbage) that can contribute to degrading the ecological condition of mariculture areas. Feng et al. (2004) hypothesized that garbage release from open water farms was likely but did not investigate further. In Hong Kong, open water fish farmers have been observed discarding garbage directly into the surrounding water as normal practice and numerous plastic feed bags have been found on the shoreline up to 4 km from the nearest fish culture zone. It is also common for fish raft ablution facilities to release untreated sewage and cleaning products directly into the water.

Physical impacts

It is known that longlines, rigging, and net cages can physically alter both hydrodynamics and habitat (Figure 5). Aquaculture structures can significantly change surface current speed and direction, induce downwelling, and reduce water exchange of bays (Grant and Bacher 2001; Zeng et al. 2015; Lin, Li, and Zhang 2016). Shi and Wei (2009) found that suspended aquaculture in Sanggou (Sungo) Bay reduced the average speed of currents by 40%, and the average half-life of water exchange was prolonged by 71%. Physical alterations to habitat can be positive or negative. Wang et al. (2015) noted that floating structures from aquaculture increase the complexity of wild fish assemblages and enhance the populations of local species. However, aquaculture structures provide a substrate for biofouling communities. While biofouling communities can help to process dissolved and particulate aquaculture waste in some cases, Qi et al. (2015) showed that ascidians that colonize scallop cages in Sanggou Bay played an important role in coupling material fluxes from the water column to the sea bed through biodeposits generated by the ascidians and through ascidian drop-off to the sea floor. That study reveals a notable 143 tons of ascidian drop-off into the bay over a growing season.

Socioeconomic impacts

The socioeconomic impacts that have been studied in China generally result from the cumulative effects of multiple chemical, ecological, or physical factors. These factors decrease farm production and increase economic loss through events such as fish kills and reduced product quality (Figure 5). For example, one consistently devastating challenge facing the Zikong scallop *Chlamys farreri* industry in northern China is the mass summer mortalities that have occurred since 1996, causing up to 85% loss of stock. It is shown that these mass mortality events are probably caused by a combination of several factors including reproductive stress, high temperature, overcrowding, poor water circulation, opportunistic invaders or predators, and hatchery inbreeding (Xiao et al. 2005).

As food safety regulators tighten monitoring and consumers become more responsible, the importance of product quality is becoming a focus; quality indices are shown to successfully identify the origin of cultured scallop *Argopecten irradians* in northern China (Xu et al. 2015). Waste substances that reduce the quality of final products, and are potentially harmful to humans, have been detected in culture organisms. These substances originate from husbandry activities, or in low-quality feed, and can contaminate products and lead to negative socioeconomic consequences. Examples of these substances include selenium, organochlorine pesticides such as hexachlorocyclohexanes, DDTs, and other PHCs (Yu et al. 2011a; Yu et al. 2011b; Wang et al. 2014a; Chang et al. 2016). To gain consumer support for suspended mariculture over the long term, it will be important to mitigate these issues through proper monitoring, regulation, and certification.

Recommendations to improve suspended mariculture

To insure the long-term sustainability of suspended mariculture, healthy aquaculture environments sufficiently protected from external stressors are required. The relatively even distribution of papers that have recommended farm management, government management, and ecological engineering measures suggests that a multidisciplinary combination of methods is probably necessary to achieve sustainability (Figure 6).

Farm management

Farm management measures can be implemented by farm managers at the individual farm level. It is suggested that carefully siting farms is one of the most effective ways to limit environmental impacts because farmed stock should be maintained at or below the carrying capacity of a site (Feng et al. 2004). Another recommendation was to move farm operations offshore, away from the semi-enclosed bays that tend to have low carrying capacities (Ferreira et al. 2009). Offshore areas are characterized by deep water and higher-order hydrodynamics that can flush farm waste away from farm areas and distribute it over larger areas for assimilation by natural processes (Feng et al. 2004).

Other farm management recommendations included improving general husbandry practices, using carefully formulated feeds and optimizing feeding regimes (Figure 6). In China trash fish is still the most commonly used feed for the culture of fed species (FAO 2014). Formulated feeds should replace trash fish because formulated feeds are generally more digestible and will result in lower feed conversion ratios and environmental impact. Formulated feeds should be high quality because many low-quality feeds have low nutritional benefit or contain contaminants that originate in the ingredients used to make the feed (Edwards 2015; Liang et al. 2016). Improving the use of pharmaceuticals for the treatment of pathogens in suspended mariculture was suggested in only one study (Xie et al. 2013). Fallowing of culture sites and dredging to remove contaminated aquaculture sediments were recommended by few studies: Feng et al. (2004) suggested moving fish rafts to new areas and halting culture activities at the original site for 1–2 years to facilitate recovery of impacted sediment. However, fallowing and dredging have not been popular probably because of the associated expense and logistics.

Governmental management

Governmental management measures must be initiated, coordinated, and regulated by relevant government departments and local municipalities. The most frequently recommended measure in this category was to improve policy and/or regulations. Suggestions for policy were centered around implementing well-regulated legislation that facilitates an industry transition to more sustainable practices. The current licensing system in China has been reviewed by (Fang et al. 2016a); licenses for sea area use and aquaculture are granted separately and once a farmer is in possession of both they can engage in open water aquaculture. In many cases, licenses have not specified the species, stocking densities, or system layouts and so aquaculture activities have proceeded unrestricted. Prior to the 1990s this system was advantageous and played an important role in the development of suspended mariculture in China. More recently, however, the lack of restrictions has, in many cases, allowed production volumes to far exceed local carrying capacities and has resulted in severe pollution and disease outbreaks (Fang et al. 2016a).

Other recommendations for governmental measures included implementing integrated coastal management (ICM), initiating ecosystem protection, establishing aquaculture associations, or implementing regulations based on the polluter pays principle (Figure 6). ICM refers to a holistic management framework that guides multidisciplinary management measures in the coastal zone (Yu et al. 2016a). In aquaculture, this can include efforts to use multidimensional models to guide management decisions across marine sectors and to guide the implementation of suitable policies (Nobre et al. 2009). Ecosystem protection measures could include the zoning of protected areas, under various levels of protection, to limit the intensity of aquaculture and support a healthy ecosystem overall (Hu 1994; Feng et al. 2004; Yu et al. 2016b). The formation of aquaculture associations is recommended to help guide farmers on husbandry practices and encourage information sharing between farmers (Liu et al. 2009; Xie et al. 2013). Implementing the polluter pays principle is also suggested and would require farmers to pay a tax on any pollution they release over and above predetermined levels (Zhou et al. 2006a; Neori 2008). A polluter pays system could be expanded further to include a nutrient credit system that allows for intra- and inter-industry nutrient credit trading based on net nutrient release or extraction (Ferreira et al. 2009; Troell et al. 2009). Farmers engaging in the cultivation of extractive species would benefit from a nutrient credit trading system because the economic value of lower trophic-level species would increase.

Ecological engineering

Ecological engineering in aquaculture addresses, quantifies, and facilitates the construction of biological systems that can assist in managing waste as a resource (Troell et al. 2009). The implementation of IMTA, large-scale mollusk farming, large-scale seaweed farming, the careful selection of production species, and large-scale echinoderm farming are all forms of ecological engineering that have been recommended in China (Figure 6).

IMTA and the large-scale cultivation of extractive species can mitigate or remediate aquaculture waste by assimilating it (Chopin et al. 2001; Neori et al. 2004). These techniques have become popular because, if species are selected carefully, they should provide an economic return when harvested. For example, filter feeding mollusks have been shown to remove suspended particulates, seaweeds can remove dissolved substances, and echinoderms remove settling debris, either directly or indirectly. Direct removal occurs when the extractive species consumes farm waste directly, such as when echinoderms feed on fish feed that has settled to the sea floor (Zhou et al. 2006b). Large-scale seaweed cultivation is proposed as a means to reduce the widespread coastal eutrophication in China because macroalgae are highly efficient at directly assimilating dissolved nutrients that are then harvested as seaweed biomass (Feng et al. 2004; He et al. 2008). Indirect removal of waste occurs when extractive species feed on the additional productivity caused by aquaculture waste, such as when bivalves feed on the increased availability of microalgae present in aquaculture zones due to higher concentrations of nutrients that promote microalgal growth (Lu et al. 2014b). Ecological engineering is becoming popular in China because of the recent, rapid expansion of mariculture production and the waste it generates, and because China has a history of cultivating and consuming species from low trophic levels.

One simple ecological engineering measure to improve the sustainability of aquaculture operations is the fundamental step of carefully selecting the species to be cultured (Luo and Yang 2012; Zhao et al. 2013). This applies to intensive monoculture and polyculture. Monoculture of extractive species such as seaweed and bivalves has been promoted in China because they cause less environmental impact compared to fed finfish (Kang et al. 2013). Monoculture of different fed finfish can also have varying degrees of impacts, depending on species diet, metabolism, and trophic level (Wu 1995). Herbivorous fish species are favored because of their plant-based diets and comparatively lower environmental impact (Williams 1997; Naylor et al. 2000). It is important to select species that are well-suited to the environmental conditions in an area because feed conversion ratios are usually more favorable where environmental conditions are optimal (Nordgarden et al. 2003). In an ecological engineering context, the selection of species for co-culture is important because the ratios of nutrients released, or assimilated, vary between species within trophic levels.

By implementing selected recommendations simultaneously, multidisciplinary approaches can help to develop a sustainable suspended mariculture industry in China. In particular, ecological engineering approaches such as IMTA can be used to augment farm- and government-level measures. The implementation of IMTA is the most frequently recommended measure for helping to reduce the impacts of suspended mariculture (Figure 6).

IMTA in China

Development of IMTA

The implementation of various forms of IMTA is happening readily in China partly because there is a growing philosophy that the waste from the production of one resource must become an input into another (Ruddle and Zhong 1988; Chopin et al. 2001). Because of the early suspended seaweed culture activity in the 1950s, the advent of suspended scallop culture in the 1960s, and the widespread adoption of suspended fish cage culture in the 1980s, IMTA has been described as the most common culture system in the coastal zone (Fang et al. 1996; Ren et al. 2014; Edwards 2015). However, the implementation of IMTA has not been homogenous. Suspended IMTA systems in open water can be characterized under one of three operational regimes: incidental (extensive) IMTA, transitional IMTA, and engineered (intensive) IMTA. Incidental IMTA is the most common and occurs when extractive species are farmed in the same semi-enclosed bay as fed species so that waste assimilation by extractive species occurs naturally (Edwards 2015). The semi-enclosed inshore bays of China are favored locations for aquaculture and so connectivity between species is facilitated by natural hydrodynamics (Ma et al. 2015). Over the years there has been a sequential development of IMTA from these incidental systems to engineered systems as more data, information, and training become available. Transitional IMTA systems are therefore systems that initially existed as incidental systems, but are being refined by farmers to intentionally optimize operation potential by integrating species from multiple trophic levels to supplement overall farm production. Engineered IMTA systems are uncommon and most examples are experimental rather than commercial (Han et al. 2013b; Yu et al. 2016c). China's leading case for a truly commercial, engineered IMTA system is Sanggou Bay in Shandong (37°05′44.5″N 122°31′39.1″E). The bay has been well researched in an IMTA context because farmers in Sanggou Bay have intentionally cultured species from multiple trophic levels in combination, and on a large scale, since at least 1996 (Fang et al. 1996; Mao et al. 2006). Finfish are produced in the inner bay, and scallops and oysters are cultivated in the mid-bay (Mahmood et al. 2016b). There is a mixed-culture zone where bivalves and macroalgae are farmed in combination in the outer-mid-bay and then toward the mouth of the bay macroalgal culture is dominant because of the optimal hydrodynamics there (Mahmood et al. 2016a). Successful nutrient transfer is shown between trophic levels and more recently scientists and farmers have worked together to improve production ratios by managing trophic levels and assessing the feasibility of various mariculture schemes (Ren et al. 2014; Liu and Su 2015).

Geographic distribution of IMTA

Research on IMTA has been heavily centered in Shandong province in northern China (Figure 2), probably because Sanggou Bay has served as a model for large-scale IMTA research since 1996 and because Shandong province is home to more than 70% of the marine research institutions in China (Fang et al. 1996; Ding, Ge, and Casey 2014). Although few studies have assessed the applications of IMTA in southern China the region is not short of valuable, commercial species from low trophic levels. For example, the seaweed *Gracilaria lemaneiformis* (Yang et al. 2015), scallop *Chlamys nobilis* (Guo and Luo 2006), and oyster *Crassostrea hongkongensis* (Lam and Morton 2003) are all commercially cultivated in southern China and can be tested in large-scale IMTA systems, but so far integrating low trophic level species with fed species remains experimental (e.g., Yu et al. 2012; Yu et al. 2014b). To elucidate potential climatic influences that may act as drivers to the success of commercial IMTA in northern China, new research could focus on commercial-scale IMTA in provinces south of Shandong. The details of extractive species that have been studied for IMTA systems in China are presented in Appendix S4: Table S1.

The benefits of IMTA in China

The potential benefits of IMTA are well reviewed internationally (e.g., Chopin et al. 2001; Neori et al. 2007; Troell et al. 2009). The benefits of IMTA in China have not been reviewed previously. China's IMTA research has been directed at the core benefits of bioremediation and/or biomitigation while other benefits have been studied less frequently (Figure 7).

Bioremediation/biomitigation

Bioremediation or biomitigation of waste products can be achieved by cultivating low trophic-level organisms to assimilate farm waste and convert it to a harvestable biomass (Troell et al. 2009). For example, suspension feeding bivalves are suitable for processing suspended particulate wastes, and seaweeds are suitable for absorbing dissolved nutrients (Zhou et al. 2006c; Wu et al. 2015a). Energy transfer between trophic levels has been confirmed in several studies using stable isotope analysis and/or fatty acid profiling (e.g., Gao et al. 2006; Jiang et al. 2013; Mahmood et al. 2016b). The bioremediation potential of several species has been demonstrated (e.g., He et al. 2008; Yu et al. 2014a; Appendix S4, Table S1). In Jiaozhou Bay the production of 200,000 tons of Manila clam has been estimated to filter the entire volume of the bay in under 1 week, substantially reducing the occurrence of eutrophication there (Xiao et al. 2007). It has been proposed that, when low trophic-level species are favored, top-down control from aquaculture can help to maintain the ecological structure and function of bays (Zhou et al. 2006d). In Xiangshan Bay it was shown that a yield of 30.4 tons of *G. lemaneiformis* removed nearly 94 kg of N and 13 kg of P and several water quality parameters including dissolved oxygen and pH were improved (Xu et al. 2008). He et al. (2016) has hypothesized that various algae can be used to extract selected, unwanted pharmaceuticals from the water. Additionally, IMTA systems are also shown to effectively sequester atmospheric CO_2 released by factories in the region (Tang, Zhang, and Fang 2011).

Increased farm production

Increased farm production is beneficial because culture organisms reach size-at-harvest more rapidly or the total harvestable biomass that can be produced in a site is increased (Neori et al. 2004; Sara et al. 2012). In Ailian Bay, Shandong, Pacific oyster *Crassostrea gigas* grew significantly larger shell heights and flesh dry weights at a fish cage area compared to a control area (Jiang et al. 2013). In Sanggou Bay, Shandong, sea urchin *Hemicentrotus pulcherrimus* have been used experimentally to control the biofouling on scallop *C. farreri* cages and scallop soft tissue grew larger, but shell size did not differ, in the presence of sea urchins (Qi et al. 2014). In Daya Bay, Guangdong, *Sargassum hemiphyllum* and *Sargassum henslowianum* had significantly faster growth rates and reached a larger size in a fish culture zone compared with naturally occurring wild populations (Yu et al. 2014b). Increased production can ultimately help to improve overall farm profitability.

Other benefits

The seven other benefits of IMTA remain poorly demonstrated and require further investigation in China but some preliminary information has been published (Figure 7).

Improved function of the surrounding ecosystem is achieved when extractive species contribute to maintaining the environmental health of mariculture areas. In Hongsha Bay, Hainan, the macroalga *Eucheuma gelatinae* and bivalve *Gafrarium tumidum* were successfully used to reduce eutrophication and maintain microalgal density at acceptable levels (Li, Yu, and Peng 2015). Macroalgae can inhibit the growth of microalgae by competition for nutrients, inhibitory allelopathy, or by reducing light penetration (Zhou et al. 2006c; Wang et al. 2007b; Yang et al. 2015).

Improved financial return and improved overall sustainability are secondary benefits of IMTA that can result from increased production, decreased stock mortality, improved product quality, and improved public opinion and social benefits. Decreased mortality of the finfish *Sebastodes fuscescens* and the scallop *C. farreri* was achieved by integrating the macroalga *G. lemaneiformis* because the algae improved the aquaculture environment overall (Zhou et al. 2006a; Mao et al. 2009). Improved product quality is possible when IMTA systems improve the composition or appearance of products. *S. hemiphyllum* cultured with fish had a higher crude protein content, favorable for its use as fodder for abalone, compared to samples harvested from the wild (Yu et al. 2014b). The yield of premium quality pearls from *Pinctada martensi* was consistently higher when co-cultivated with the macroalga *Kappaphycus alvarezii* (Wu et al. 2003). The social benefits and improved public opinion associated with IMTA remain undemonstrated in China, but the possibility of these benefits has been discussed and should be investigated properly to help motivate wider implementation of IMTA (Troell et al. 2009; Fang et al. 2016b; Tang, Ying, and Wu 2016).

Soto (2009) proposed the potential for IMTA systems to assist in the control of aquaculture pathogens. In IMTA systems internationally, bivalves can help control luminous bacterial disease in shrimp (Tendencia 2007). In China the sponge *Hymeniacidon perleve* collected from the Yellow Sea effectively removed the common aquaculture pathogens *Escherichia coli* and *Vibrio anguillarum II* from seawater (Fu et al. 2006). The mechanisms that drive the control of pathogens in IMTA systems remain unclear, but the preliminary evidence presented here warrants further investigation.

Improved social benefits and public opinion have been associated with the implementation of IMTA (Fang et al. 2016b). Potential social benefits could result from increased employment on farms that practice IMTA or in industries that support IMTA, such as hatcheries that are necessary to ensure a steady supply of IMTA species seed stock. Improved public opinion could arise because IMTA can have a reputation for being an environmentally friendly farming technique (Alexander et al. 2016). This in turn would present opportunities for producers to eco-label premium products. However, in China, the potential for social benefits and improved public opinion associated with IMTA requires further investigation.

Potential challenges to IMTA in China

The challenges facing the development of marine industries in China were reviewed by Ding, Ge, and Casey (2014). There are several challenges facing IMTA that could hinder its implementation.

Limited new technology and skills

Despite China's role as the global leader of aquaculture production, the country has been slow in adopting new skills and technology to improve aquaculture techniques (Li et al. 2011). This is particularly true in the suspended mariculture sector where the focus has been on expanding production without technical progress or improvements in farm efficiency. Husbandry techniques remain largely traditional and inefficient. Engineered IMTA systems, at any scale, require advanced technology and skills for activities like water quality monitoring and regular assessments of stock growth and health (Mao et al. 2006). Large-scale IMTA systems are particularly challenging because, in most places, there is not enough information on how the separate system components interact and function as a whole (Fang et al. 2016b). To overcome these difficulties, training programs in modern husbandry, recruitment of a younger generation of aquaculturists, and the use of advanced aquaculture technology are recommended. Furthermore, a division in expertise in the suspended mariculture supply chain is encouraged such that individual production components are managed optimally.

Decreasing production of low trophic levels

Globally there has been an increase in the weighted mean annual trophic level of cultivated species, and the number of finfish species under commercial cultivation (Campbell and Pauly 2013). There has been a trend of "farming up the food web," resulting in a decline in the production of low trophic-level species from aquaculture (Tacon et al. 2009). Market prices for low trophic-level organisms in China will probably determine the future scale of their culture (Fang et al. 1996). Although finfish mariculture production levels remain low, their proportion in total mariculture output has been increasing: from 1994 to 2004, 2014 and 2015 production expanded from 2.93% to 4.42%, 6.56%, and 7.26% of total production (MOA 2016). To prevent a continued move away from low trophic-level species, further research on alternate high-value uses of these organisms is recommended. In addition, the potential for implementing inter-industry nutrient trading schemes based on the extractive capabilities of low trophic-level species should be explored.

Biogeographic and temporal barriers

Biogeographic barriers arise from the wide longitudinal distribution of China's coastline. Temporal barriers arise from seasonal changes to local conditions. Aquaculture techniques and species that are used in the cold north are not suitable to the tropical south. The environmental implications of aquaculture operations are case specific (Gao et al. 2005). In Yantian Bay, in Fujian, no commercial seaweed cultivation occurs in the warm seasons from late spring to early autumn, whereas in north China various species of macroalgae can be cultivated all year (Wu et al. 2015a). Optimization of stocking ratios at the species level is key to implementing IMTA systems (Tang et al. 2015), but ratios of fish, primary producers, filter feeders, and deposit feeders vary seasonally based on farm production regimes and the metabolic rates of the culture organisms (Ren and Zhang 2016). To overcome these barriers, exploration of indigenous species that could hold commercial value must be conducted to expand site- and season-specific lists of IMTA candidate species. Where information is lacking, a precautionary approach is recommended. The cultivation of extractive species should be prioritized while the addition of fed species should proceed cautiously based on recommendations from site-specific environmental monitoring.

Negative feedbacks

Negative feedbacks can result because newly added extractive species can themselves impact the environment or because the interactions between multiple species in a small area can have adverse consequences. In bivalve aquaculture, for example, there are carrying capacity issues to consider due to the consumption of food directly from the water column (Duarte et al. 2003; Zhou et al. 2006c). In addition, bivalves may only partially assimilate large volumes of suspended particulates that are then converted to settling matter and can substantially contribute to the onset of anoxia in benthic environments (Ren and Zhang 2016). In Jiaozhou Bay, Shandong, the strong top-down control of shellfish aquaculture impacts the spawning, nursery and feeding grounds of benthic fish (Xiao et al. 2007). Macroalgal cultivation can also impact the environment. In Sanggou Bay *Saccharina japonica* was shown to lose culture biomass through loss of entire individuals, breakage of thalli, and erosion of distal tissue that resulted in 61% of total carbon and 54% of total nitrogen produced in the tissues being lost to the environment (Zhang et al. 2012). There is also the possibility that macroalgae can totally outcompete phytoplankton for essential nutrients, inhibiting the food source of filter feeding bivalves (Duarte et al. 2003).

Some interspecies interactions in IMTA are not favorable. Tissue samples from the macroalga *S. henslowianum* cultivated near fish cages showed significantly higher concentrations of the metals Cr, Pb, and Cd compared with samples from a wild population, probably due to the high concentration of these metals in feed and antifouling paints (Yu et al. 2014b). To realistically assess the suitability and benefits of IMTA at local scales, the positive and negative feedbacks of implementing these systems must be studied (Hawkins et al. 2002).

Conclusions

In China mariculture produces more biomass per hectare than freshwater aquaculture. Mariculture production in Shandong, Fujian, Guangdong, and Liaoning is well established, but there is scope for the development of mariculture in Hebei, Jiangsu, Zhejiang, Guangxi, and Hainan. While the suspended mariculture industry is still heavily based on traditional and inefficient methods, the likelihood of fully utilizing the space suitable for mariculture development will depend on the implementation of sustainable industry practices. The impacts from suspended mariculture have been well studied in Shandong and Guangdong, but there is limited information for all other provinces. Impacts can be categorized as chemical, ecological, physical, and socioeconomic. Chemical impacts have been well studied but relatively few studies have focused on ecological, physical, or socioeconomic impacts. Minimizing impacts, and preserving the condition of suspended mariculture areas, is probably best achieved by a combination of management measures at government department, farm management, and ecological engineering levels. Of all the recommendations made in published research, implementing IMTA is the most frequently recommended. However, Shandong remains the only province in which the applications of IMTA have been methodically investigated. Further research in all provinces is encouraged. The benefits of bioremediation, biomitigation, and increased farm production have been the most frequently demonstrated, but little information has been published on other potential benefits. The challenges currently facing the expansion of engineered, commercial IMTA include limited implementation of new technology, limited development of new skills, decreasing production of low trophic-level species, biogeographic and temporal barriers, and negative system feedback.

Further research is essential for developing engineered IMTA systems that are well adapted to a variety of species and environmental circumstances. Fundamental research such as the exploration of candidate IMTA species, IMTA system designs, and the microeconomics of IMTA systems is necessary. In addition, forward-looking research into supporting industries and the implementation of affordable technology is recommended. Husbandry practices could move toward automation of basic tasks such as water quality monitoring, feeding, and size sorting. Aquaculture information management systems could be developed for stock health monitoring, regulating food safety, and information sharing amongst aquaculture associations. To facilitate the continued growth of IMTA in China, research should be coordinated around a relevant framework that forms the basis of a research, development, and implementation continuum (Figure 8).

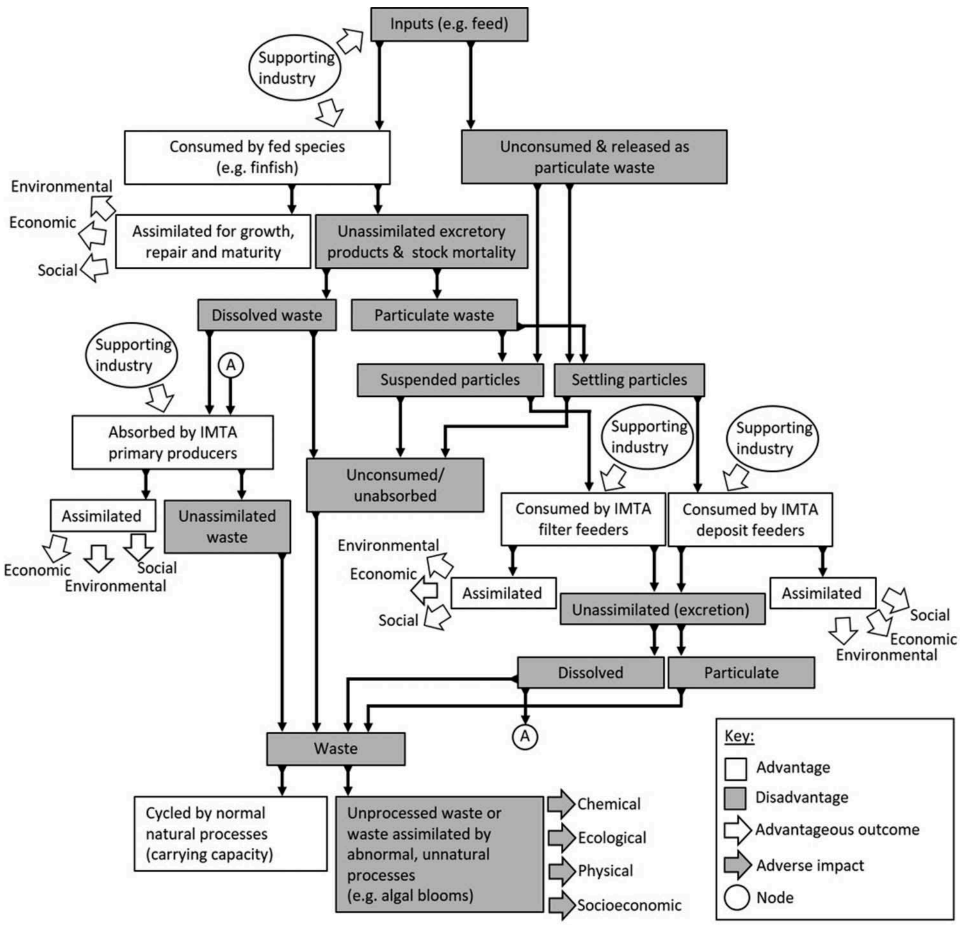

Figure 8. Integrated Multi-Trophic Aquaculture (IMTA) concept model outlining the various system components in the production process that could be incorporated into a research, development and implementation continuum for the expansion of engineered IMTA in China.

Improving the sustainability of suspended mariculture is a prerequisite to increasing the supply of marine products from China. Despite several clear challenges facing commercial IMTA, its implementation and development are encouraged. A move toward implementing engineered IMTA systems across China could help to alleviate some of the anthropogenic pressure facing China's coastal zones and increase the environmental, economic, and social sustainability of the suspended mariculture industry.

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Disclosure statement

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ORCID

Reece Wartenberg http://orcid.org/0000-0002-5190-8102

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THE FEASIBILITY OF INTEGRATING THE NOBLE SCALLOP *MIMACHLAMYS NOBILIS* WITH EXISTING FISH MONOCULTURE FARMS IN THE SOUTH CHINA SEA: A BIOECONOMIC ASSESSMENT FROM HONG KONG

REECE WARTENBERG,[1,2,3]* KHEM LIMBU,[1,2] LIMIN FENG,[1,3] JIA JUN WU,[1,3] LEO L. CHAN,[1,3,4] TREVOR C. TELFER[5] AND PAUL K. S. LAM[1,2,3]

[1]*State Key Laboratory in Marine Pollution, City University of Hong Kong, Tat Chee Avenue, Kowloon, Hong Kong SAR, China;* [2]*Department of Chemistry, City University of Hong Kong, Tat Chee Avenue, Hong Kong SAR, China;* [3]*Research Centre for the Oceans and Human Health, Shenzhen Key Laboratory for Sustainable Use of Marine Biodiversity, City University of Hong Kong Shenzhen, Research Institute Building, Shenzhen, Guangdong 518057, China;* [4]*Department of Biomedical Sciences, City University of Hong Kong, Tat Chee Avenue, Hong Kong SAR, China;* [5]*Institute of Aquaculture, University of Stirling, Grange Road, Stirling FK9 4LA, United Kingdom*

ABSTRACT The environmental implications of integrated multitrophic aquaculture have been well studied in China, but few investigations have empirically explored potential economic benefits. This study investigated the technical and economic feasibility of physically integrating the noble scallop *Mimachlamys nobilis* (Reeve, 1852) with existing fish monoculture farms in Hong Kong. Scallops were grown for 201 days from June to December in lantern nets hung directly from fish farm platforms at treatment depths of 1, 3.5, and 6 m. Only the 1-m treatment attained the target mean height-at-harvest of 80 mm. Fitted von Bertalanffy growth functions showed significant differences in growth performance between depths. The von Bertalanffy growth function projected that the 3.5- and 6-m treatments would require an additional 26 and 59 days of culture to reach 80 mm. Mortality was significantly lower at 1 m (53% ± 12.5%) compared with those at 3.5 m (70% ± 9.0%) and 6 m (83% ± 4.5%). The slower growth and higher mortality at 3.5 and 6 m were probably due to periodically low oxygen which dropped to 4.96, 3.08, and 1.73 mg L^{-1} at 1, 3.5, and 6 m, respectively, in midsummer. A bioeconomic assessments of two typical farm sizes was conducted; small (45 m^2) and large (315 m^2). The initial investment, discounted payback time, and 10-y net present value of the projects was US$5,485.51, 3 y, and US$20,211.33, respectively, for the small farm and US$27,659.03, 2 y, and US$227,406.49, respectively, for the large farm. Sensitivity analysis revealed that the profitability of operations was sensitive to changes in mortality and sales price. This study has confirmed that physically integrating *M. nobilis* at existing fish farms is technically and economically feasible.

KEY WORDS: scallop, *Mimachlamys nobilis*, bioeconomic, economic, integrated multi-trophic aquaculture, feasibility

INTRODUCTION

Cage and longline aquaculture in the open sea, collectively called suspended aquaculture, has been expanding to help meet the growing global demand for seafood. A limitation to the suspended aquaculture of fed species such as finfish is that cage systems are essentially open and so intensive production can pollute the supporting water body (Cao et al. 2007, Chen et al. 2007). In China, at least 18 adverse impacts including chemical, ecological, physical, and socioeconomic impacts have been shown to originate from suspended aquaculture (Wartenberg et al. 2017). If the environmental, economic, and social sustainability of suspended aquaculture is to be insured over the long term, then farming systems that minimize negative impacts and improve consumer perceptions are needed (Ridler et al. 2007).

One frequent recommendation for improving suspended aquaculture is integrated multitrophic aquaculture (IMTA). Prototypical IMTA integrates low–trophic-level, extractive species with fed finfish such that the extractive species can assimilate waste and produce additional, commercially valuable secondary products (Chopin et al. 1999, Neori et al. 2004, Barrington et al. 2009). Research on IMTA has shown that macroalgae, shellfish, and echinoderms can process dissolved nutrients, suspended particulates, and settling particulates at cage farming areas, thereby remediating some of the waste released from fish farms (Nobre et al. 2010, Shi et al. 2013, Chopin 2015).

In China, research on IMTA in suspended aquaculture systems has been going on since the mid1990s, but important knowledge gaps remain (Fang et al. 1996, Qian et al. 1996, Nunes et al. 2003, Ferreira et al. 2009). Research has been heavily focused in northern China and few studies have quantified the economic implications of IMTA (Shi et al. 2013, Wartenberg et al. 2017). Because of the wide longitudinal expanse of China (17–40° N), research on IMTA candidate species from all regions is necessary to identify production opportunities and bottlenecks, and to facilitate the commercial adoption of engineered systems. In southern China, there is only limited information on IMTA and the question of economic viability has not been addressed (e.g., Yu et al. 2013, 2014a, 2014b, 2016). Quantitative information on the economics of IMTA is essential for industry adoption because unless farmers can see a direct financial benefit, it is unlikely that IMTA would be implemented commercially.

One promising candidate species for use in engineered IMTA systems in the South China Sea is the noble scallop, or huagui scallop, *Mimachlamys nobilis* (Reeve, 1852). The noble scallop is the primary commercial scallop species from southern China and is commonly sold at shell heights (SH) of 65–80 mm (Guo & Luo 2016). The natural distribution of *M. nobilis* is from 19 to 22° N. The species grows faster, and to a larger size, than the zhikong scallop, *Chlamys farreri* (Müller, 1776) which

*Corresponding author. E-mail: reece.wartenberg@gmail.com
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is farmed in northern China and accounts for 60% of scallop production in the country (Guo & Luo 2016). There are hatcheries in Guangdong and Fujian that produce *M. nobilis* spat, and so there is an established supply of seed. Despite the suitability of *M. nobilis* for inclusion in IMTA systems in southern China, no previous study has attempted to directly integrate this scallop at existing fish farms.

Hong Kong SAR is a region in the South China Sea that has designated aquaculture zones exclusively occupied by fish monoculture operations. Fish are farmed in square net cages, typically 4 × 4 × 4 m, suspended under floating platforms. Net cages are usually accompanied by open deck areas that provide space for husbandry activity. These collective floating structures are known as fish rafts. This style of aquaculture is used widely throughout Asia, and so research findings from IMTA in Hong Kong could be applied to the rest of the South China Sea with minimal modifications. Hong Kong is situated directly adjacent to Daya Bay which, in the past, was reported to have a naturally high abundance of *Mimachlamys nobilis* but the species has been commercially exploited in recent years (Guo & Luo 2016, Lü et al. 2017). Preliminary work on IMTA in Hong Kong used the mussel *Perna viridis* (Linnaeus, 1758), stable isotope analysis and fatty acid profiling to show that *P. viridis* could assimilate fish farm waste when cultivated adjacent to fish cages (Gao et al. 2006). Despite exhibiting good growth rates in field trials *P. viridis* remains commercially unutilised in Hong Kong because it has a low market value (Wong & Cheung 2001). The commercially valuable *M. nobilis* is, therefore, a promising candidate species for use in IMTA systems in the region.

The aim of this study was to determine if the physical integration of *Mimachlamys nobilis* at existing fish monoculture rafts is technically and economically feasible. Technical feasibility was assessed by growing *M. nobilis* at a commercial fish farm in Hong Kong using lantern nets suspended from the original raft structure. The field trial was carried out over 7 mo to establish baseline biological, technological, and economic factors associated with growing *M. nobilis* to produce a live product for distribution to local wholesale markets. Economic feasibility was assessed by coupling growth and mortality functions with empirical economic data to produce a comprehensive bioeconomic assessment of a potential scallop enterprise. To forecast the long-term viability of the operations, the bioeconomic assessment was simulated for two typical farm sizes over a 10-y period.

MATERIALS AND METHODS

Site

Scallops were cultivated at Kau Sai fish culture zone (FCZ), one of 29 areas designated for suspended aquaculture in Hong Kong. Kau Sai FCZ (22°21′ N, 114°19′ E) lies in a small, semienclosed bay within Port Shelter in the eastern waters of Hong Kong (Fig. 1). The FCZ has a total area of 46,200 m^2 and, at the time of the experiment, 13,057 m^2 was licensed for fish rafts. The fish stock in the culture zone is maintained up to 500 t and stocked at an average density of 4.5 kg m^{-3}. The maximum depth under the fish raft used for the scallop field trial was 14 m at high tide. Typical tidal amplitudes in the area are 1–2 m. The water temperature in Port Shelter can range from 15°C in winter to 29°C in summer whereas salinity is normally between 28 and 34 depending on rainfall (EPD 2016).

Scallop Stock

Scallops ($n = 723$, SH = 44 ± 5 mm) were dry-transported in polystyrene boxes at a temperature of approximately 20°C from a lantern-net system in Fujian, Peoples Republic of China. Total transport time from packing to stocking at the study site was approximately 8 h. On arrival at the farm each box of scallops, containing 350 individuals, was allocated to an aerated 100 L tank for acclimation. Wild *Mimachlamys nobilis* occupy habitats with water temperatures ranging from 8°C to 32°C, with 20°C–25°C considered optimal (Guo & Luo 2016). Although the optimal rate of temperature acclimation has not been determined for *M. nobilis*, relatively large scallops are generally resilient to changes in temperatures within their optimal range (Shumway & Parsons 2016). The water temperature of the tanks was, therefore, increased at a rate of 4°C/h by adding ambient seawater until it matched the temperature of the seawater of the fish farm at 24°C. After temperature acclimation, scallops were then placed in lantern nets that were suspended directly from the platforms of the fish raft for a 2-wk environmental acclimation period. The stocking density of each net layer was 45% surface area coverage during acclimation. Mortality that may have been caused by transport and the acclimation process was taken as the number of dead scallops at the end of the 2-wk acclimation period (Sarkis et al. 2005).

Experimental Design

Scallops were grown in 14-layer, 2-cm monofilament, 50-cm diameter lantern nets in the central part of a fish monoculture farm that had 94 fish cages that were 4 × 4 × 4 m each. Lantern nets were hung directly from the existing raft platforms in the space between fish cages such that normal fish husbandry activities were unaffected by the addition of scallops. Total fish stock was maintained up to 27 t depending on normal husbandry activities. The pompano *Trachinotus blochii* (Lacépède, 1801) was cultured in all cages directly adjacent to the scallops whereas various Serranidae and Lutjanidae were cultured in other areas of the raft.

Scallops were farmed for a period of 201 days from May 29 to December 16, 2016, through the peak of summer when water temperatures are warmest because this has been identified as the optimal period for *Mimachlamys nobilis* growth (Guo & Luo 2016). Each lantern net layer was considered one replicate and scallops were stocked at a density of 45% surface area coverage (42 scallops/layer). Scallop farmers in Southern China will typically stock scallops covering an area of 60%–80% (Guo & Luo 2006). A stocking density of 45% was used as a precautionary measure against the possibility of reduced growth at higher stocking densities during this baseline study. To avoid complications associated with acute lantern net biofouling, such as the inhibition of food supply to scallops, fouled nets were replaced with clean nets during monthly sampling events. Regular net replacement is a common measure used to reduce biofouling in suspended scallop aquaculture (Qi et al. 2014).

The lantern net method allows farmers to grow scallops across the full depth range of the water column. In the protected bays of Hong Kong, however, strong water column stratification is common during the summer monsoon season and areas close to the sea floor can be anoxic year-round because of sludge build up (Yin 2002, Zhou et al. 2012). To test for potential differences in scallop production at different depths, three depth

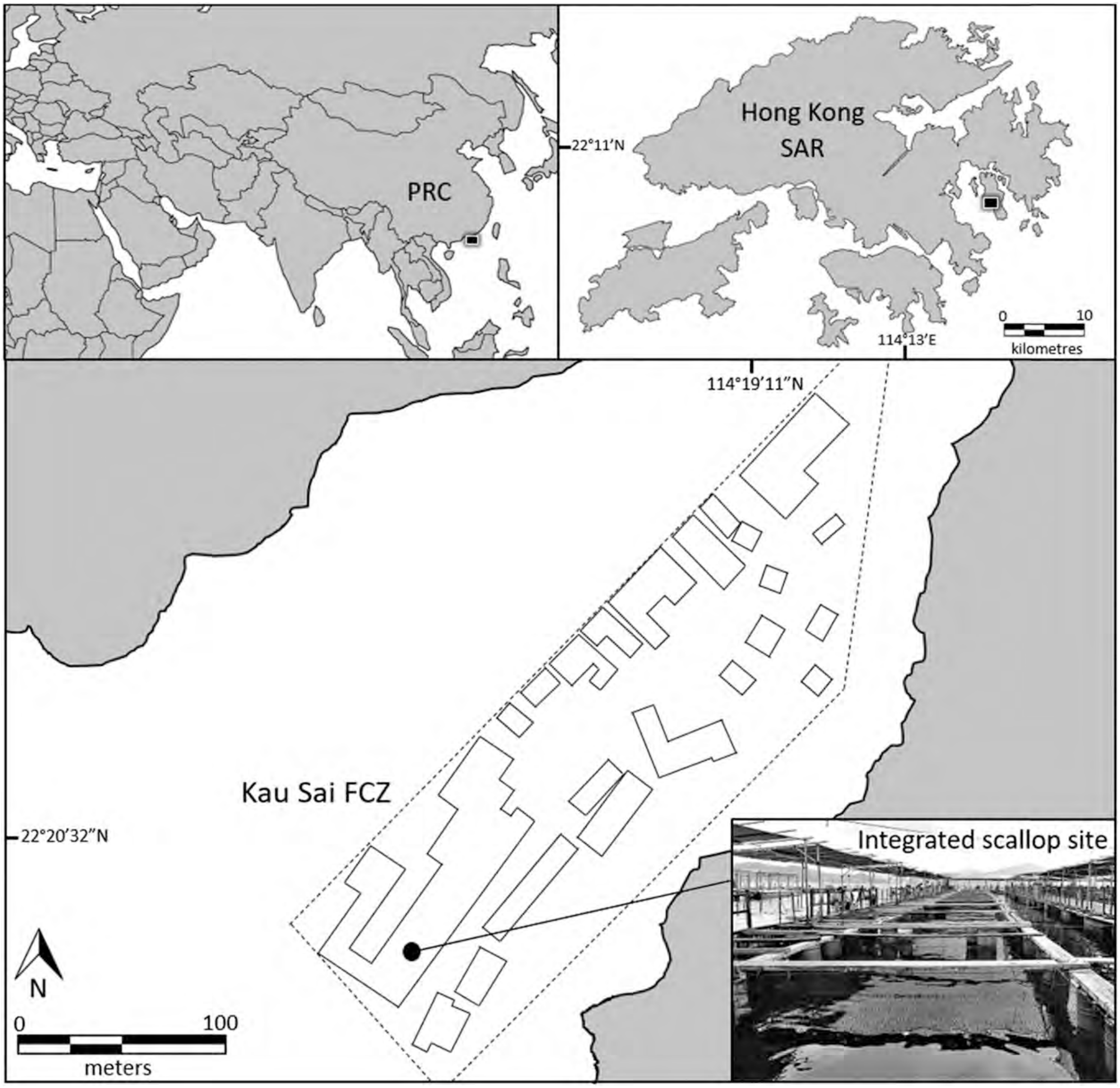

Figure 1. Map of the Kau Sai FCZ in Hong Kong SAR indicating the site used for the integrated scallop grow-out experiment. PRC, People's Republic of China.

treatments were selected; 1 m ($n = 6$), 3.5 m ($n = 3$), and 6 m ($n = 6$). To afford greater experimental control and to prevent pseudoreplication between and within treatments, lantern net layers above and below the depth classes were left empty. The shallowest treatment was set at 1 m because it was anticipated that this would be shallow enough to test for potential exposure to low salinities from monsoon rain—it is a common perception among local farmers that animals cultivated near the surface are susceptible to high mortality from monsoon rain, but no previous study has confirmed this hypothesis. The deepest treatment was set at 6 m because it was expected that this would be shallow enough to avoid complications associated with periodic hypoxic conditions in the lower few meters of the water column (Yin 2002), and would be deep enough to provide biological data on the potential 3-dimensional use of the upper 6 m of the water column.

Environmental Parameters

Environmental parameters were measured on 26 occasions over the study period, at least biweekly. Temperature, oxygen, salinity, and total chlorophyll were measured using a YSI sonde EXOII (© Xylem) which was deployed at three predetermined, discrete locations adjacent to the scallop lantern nets at approximately midday. The sonde was deployed to a maximum depth of 12 m to avoid contacting the sea floor which had a maximum depth of 14 m at full high tide. Suspended particulate matter (SPM) concentrations were determined using a water sampler to collect triplicate 1 L water samples from treatment depths. Water was filtered using preweighed and preashed glass fiber filter papers (GC-50, © Advantec) before transport back to the laboratory for filter freeze drying and weighing.

Growth and Mortality

Scallop SH, and the number of dead scallops, was assessed monthly. Shell height was measured to the nearest mm using Vernier callipers. Dead scallops included gapers (newly deceased with soft tissues present), boxes (shells without soft tissue), and disarticulated shells (separated valves) that were removed from lantern nets monthly (Xiao et al. 2005). Growth was modeled by fitting a von Bertalanffy growth function (VBGF) to height-at-time data for the culture period. Some previous studies have used variations of the original VBGF, referred to as the specialized VBGF, to model scallop growth (Taylor et al. 2006, Mendo et al. 2011). To avoid statistical overfitting, the original form of the VBGF was used in the present study. The VBGF was expressed as $H_t = H_\infty(1 - \exp[-K(t - t_0)])$, where H_t is the height at age in mm, H_∞ is the predicted asymptotic height, K is a growth coefficient representing the rate at which individuals approach H_∞, and t_0 is the age at zero length. Curves were fitted by minimizing a negated normal log-likelihood function. A likelihood ratio test was used to test the null hypothesis that there were no differences in VBGF parameters between treatments. Parameter variability was calculated using a parametric bootstrapping procedure with 1,000 iterations to determine SE (Efron 1982, Buckland 1984). As scallops were harvested before reaching their maximum reported height of 120 mm (Guo & Luo 2016), the VBGF was first fitted by optimizing all parameters to compare H_∞ between treatments, and then by fixing H_∞ at 120 mm to compare growth coefficients (K) between treatments. To facilitate between-study comparisons of growth, specific growth rate (% day^{-1}) was calculated as $\mathrm{SGR} = [(\ln H_2 - \ln H_1)/t] \times 100$, where H_1 and H_2 are the initial and final SH and t is the interval (in days) between H_1 and H_2. Mortality data were used to estimate instantaneous total mortality (Z) as the inverse-variance weighted average of a catch-curve analysis (Ricker 1975). To test for differences in mortality between treatments, Kaplan-Meier survival curves (Kaplan & Meier 1958) were compared using log-rank tests (Mantel 1966, Mendo et al. 2011).

Shell Biofouling Index

Although lantern net biofouling was minimized by replacing nets monthly, the fouling on scallop shells was not removed unless it impeded measurements of SH. Previous work, reviewed by Adams et al. (2011), has shown that shell biofouling can significantly reduce growth and increase mortality to levels that can undermine farm viability. To test if high biofouling may explain the high mortality observed in July and August of the present study, the shells of 30 deceased scallops from each treatment were transported back to the laboratory after the August sampling. Fouled shells were dried at 60°C to constant weight and weighed. Biofouling was removed with a scraper before cleaned shells were weighed. Biofouling dry weight was calculated as shell weight loss after biofouling removal. The biofouling index was calculated by dividing the dry weight of the biofouling by the dry weight of the fouled shell and multiplying by 100.

Condition Indices

In China, high quality live scallops have a large adductor muscle and full gonad. For the assessment of the condition of these soft tissues additional scallops were held in additional lantern nets suspended at 3.5 m for periodic harvesting. Soft tissue condition was assessed at the start (29/05, $n = 18$), middle (03/09, $n = 38$), and end (16/12, $n = 35$) of the culture period. Adductor muscle, gonadosomatic and "remaining tissue" indices were calculated by dividing the weight of the relevant tissue by the total weight of soft tissue and multiplying by 100 (González et al. 2002, Taylor et al. 2006). To test for differences in biofouling and tissue indices between treatments, data homoscedasticity was tested using Levene's test and the normality of treatment residuals was tested using Shapiro–Wilk's test. Analysis of variances were then used to test the null hypothesis that the treatment means were equal.

Economic Feasibility

A precautionary approach was used when compiling the business model used in the economic feasibility assessment because an integrated scallop–fish farm would be the first of its kind in Hong Kong. The assessment assumed that all lantern nets would be suspended at a depth of 1 m because of the favorable growth and mortality demonstrated by scallops from that treatment. The production system was based on a single annual stocking of *Mimachlamys nobilis* at the beginning June for their final stage of grow-out from 45 mm SH. Complete stock harvest occurred in December when the scallops reached 80 mm mean SH. This simple system was selected because it does not require substantial additions of equipment or labor and would be straightforward for farmers to implement as an initial scallop enterprise. The estimated capital and operating expenses that would be incurred were used to determine the net returns from the scallop enterprise simulated over 10 y. Monetary values in the assessment were as of September 2017 and have been converted from Hong Kong dollars to U.S. dollars at a rate of HK$7.80:US$1.00 to facilitate international comparisons. Simulations were run assuming an annual interest rate of 5% (retrieved July 20, 2017 from HSBC Hong Kong), an annual inflation rate of 3.58% (average annual inflation in Hong Kong from 2006 to 2016), and a profit tax of 15% (as for unincorporated businesses in the region). Two representative raft sizes were evaluated; small (45 m^2, nine fish cages, 2.6 t fish standing stock, 48 active lantern nets, and two existing staff) and large (315 m^2, 70 fish cages, 20.2 t fish standing stock, 340 active lantern nets, and six existing staff), based on mean raft sizes for small and large rafts in FCZ in Hong Kong.

Expenses

It was assumed that all fixed capital and operating expenses were carried by the existing fish monoculture operation. These included the raft structure, moorings, vessels, existing permanent staff, and licenses. Costs associated with the scallop operation were, therefore, allocated to variable capital expenses, variable operating expenses, and the financing costs associated with a 5-y bank loan to fund the initial expenses required to establish a scallop enterprise. Precise costing was obtained using the actual expenses from the grow-out trial. In cases where additional capital equipment would be necessary for larger systems, costs were based on actual quotations from suppliers. For example, the cost of supplementary flotation (200 L HDPE barrels) required to support the additional weight of full and fouled lantern nets was calculated and included in the assessment. The costs associated with additional labor was allocated to four tasks; scallop stocking on arrival, bimonthly lantern net replacement to limit net fouling, bimonthly lantern net cleaning to remove net fouling, and final harvest and shell cleaning before distribution. The additional labor that would be necessary for a full-scale scallop operation was calculated based on the time taken to complete these tasks during the field trial and was costed based on the hiring of part-time staff as needed. Animal health and food safety testing were not included because routine monitoring is coordinated by the Agriculture, Fisheries and Conservation Department of Hong Kong.

Revenue

Revenue estimates were made using pricing data from the Hong Kong Fish Market Organisation (retrieved on May 22 and July 21, 2017). The standard mass metric used in markets in China is the *catty*, but the specific mass of one catty can vary by region. In Hong Kong, one catty is equivalent to 606 g (approximately six 80-mm scallops). The mean wholesale market price for scallops over the period was US$5.76 (HK $45.00) per catty. A wholesale mark-up of 30%, typical in local seafood markets, was used to determine the price received by farmers and was US$4.03 (HK$31.50). Annual net revenue was determined by subtracting total costs from gross revenue.

Bioeconomic Assessment

The bioeconomic assessment was compiled using parameters from the VBGF, the mortality (Z) function, total expenses, and net revenue to evaluate the profitability of the scallop enterprise (Taylor et al. 2006, Mendo et al. 2011). The number of lantern nets that could be integrated at a raft was calculated by evaluating the number of fish cage sides available for lantern net hanging at a density of 1 lantern net/m. Key parameters used in the assessment are given in Table 1. The initial scallop stocking density per layer ($SD_{initial}$) was calculated as $SD_{initial} = SD_{harvest}/(1 - Z)$, where $SD_{harvest}$ is the target stocking density at harvest and Z is the anticipated mortality based on data from the field trial (Table 1). The standard economic valuation metrics net present value (NPV), internal rate of return (IRR), and the discounted payback time (DPBT) were used to assess the profitability of the initial investment over a 10-y operation (Penney & Mills 2000). The NPV was calculated as $NVP = \sum_{t=0}^{n} \frac{C_t}{(1+r)^t}$, where C_t represents the discounted annual cash flows, t is the time of the cash flow, n corresponds to the lifetime of the investment, and r is the discount rate. The IRR was calculated by solving the NPV equation for r when the NPV = 0. The DPBT was calculated by adding the net revenues year-by-year to determine the year in which the total surpassed the initial investment. The DPBT was restricted to whole numbers, rounded up, because the business model was structured around a single annual harvest at the end of the year. A sensitivity analysis was used to simulate the effect of a ±30% change in lantern net prices, seed stock price, transport mortality, growth (K), grow-out mortality (Z), minimum wage, and wholesale market price on the NPV of the investment. In running the assessment, it was assumed that the demand for live scallops was higher than supply, which is reasonable considering that this operation would be the first of its kind in Hong Kong and all scallops currently sold locally are imported.

RESULTS

Environmental Parameters

The water column at Kau Sai FCZ exhibited clear temperature, oxygen and salinity stratification from the start of the culture period in June until mid-September (Fig. 2). From mid-September to the end of the culture period in December these parameters were homogenous across depth classes. The warmest daytime water temperature was 29.13°C and was observed at 1 m in August. All treatments dropped to a low of 21.28°C in December. The lowest salinity of 30.61 was observed at 1 m on July 15 following heavy monsoon rain which was the same day that the minimum oxygen concentration of 1.73 mg L^{-1} was observed at 6 m. There was no correlation between chlorophyll and SPM concentrations at 1 m (r = –0.13), 3.5 m (r = 0.31), and 6 m (r = 0.05).

Growth and Mortality

When VBGF were fitted to the data by optimizing H_∞, K, and t_0, the growth curves were significantly different between the 1- and 6-m treatments (X^2 = 17.460, 3 *d.f.*, P = 0.001), but the 3.5-m curve was not significantly different from the curves

TABLE 1.

Baseline parameters used in the bioeconomic assessment of integrated noble scallop *Mimachlamys nobilis* farming at existing small and large fish monoculture rafts in Hong Kong.

Parameter	Unit	Value	Description
Growth (VBGF K)	VBGF K	1.00	Data from field trial, 1-m treatment (Table 2)
Grow-out duration	mo	7	Based on field trial and VBGF K
Mortality	%	53	Data from field trial, 1-m treatment (Fig. 3)
Size-at-stocking	mm	45	Representing scallops ready for the final stage of grow-out
Size-at-harvest	mm	80	Common market size (Guo & Luo 2016)
Scallops/layer at stocking	pcs	32	Back-calculated from anticipated mortality (33% surface area)
Scallops/layer at harvest	pcs	15	Reach maximum stocking density of 50% by harvest

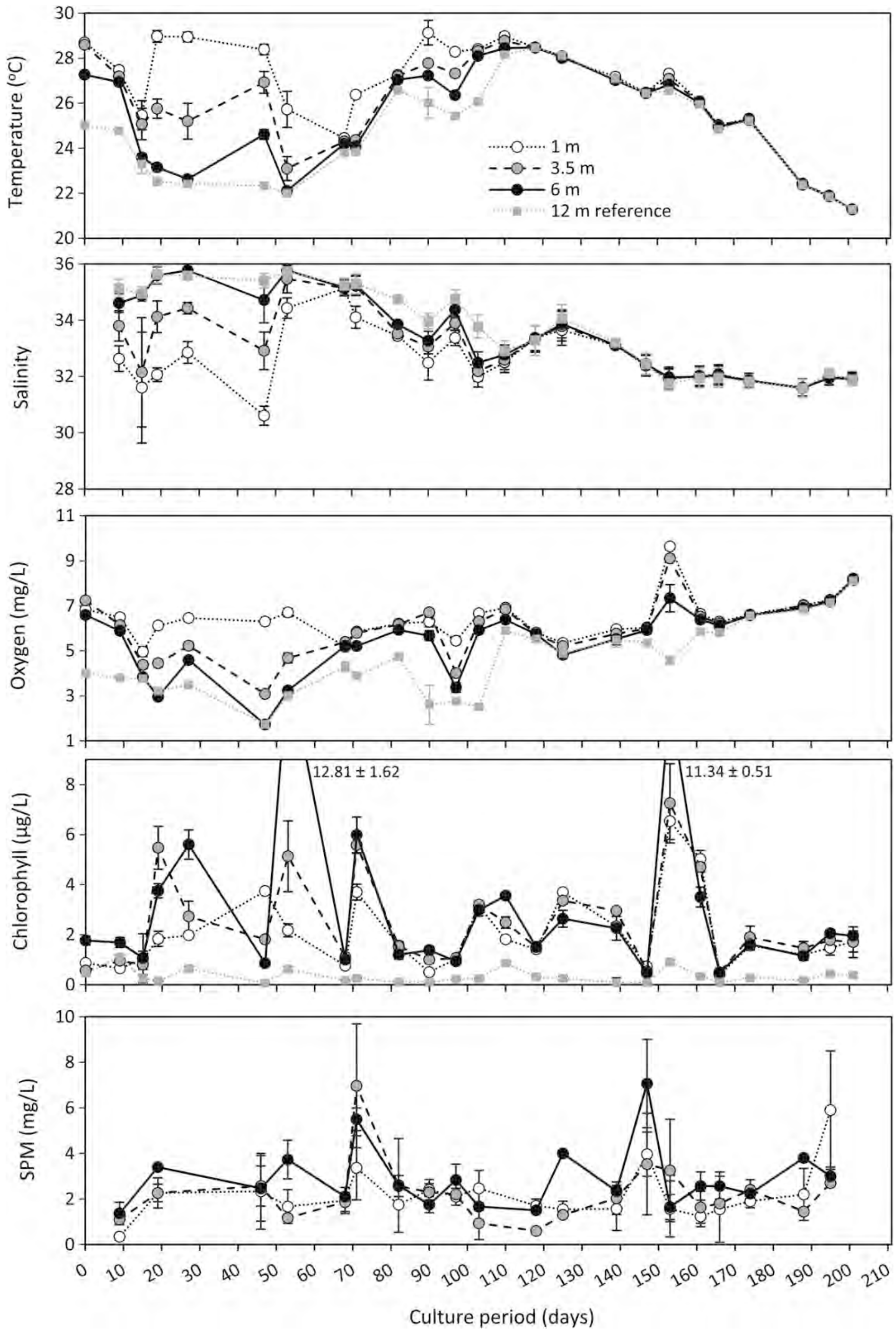

Figure 2. Temperature, salinity, oxyen, total chlorophyll, and SPM recorded at *Mimachlamys nobilis* treatments depths of 1-, 3.5-, and 6-m at the Kau Sai FCZ from May 29 to December 16, 2016. Reference data from 12-m are included to show environmental conditions near the sea floor.

for 1-m ($X^2 = 4.085$, 3 *d.f.*, $P = 0.252$) or 6-m ($X^2 = 2.451$, 3 *d.f.*, $P = 0.484$). H_∞ was highest for the 1-m treatment (128 ± 21.52 mm) but also generated the lowest growth coefficient ($K = 1.00 \pm 0.28$) (Table 2). When the VBGF was fitted with H_∞ fixed at 120 mm, the VBGF were still significantly different between the 1- and 6-m treatments ($X^2 = 13.717$, 2 *d.f.*, $P = 0.001$), and the 3.5-m growth curve was still not significantly different from the curves for 1-m ($X^2 = 4.187$, 2 *d.f.*, $P = 0.123$) or 6-m

TABLE 2.

von Bertalanffy growth model parameter estimates (mean ± SD) for *Mimachlamys nobilis* cultivated at the Kau Sai FCZ in Hong Kong.

Treatment	Height at harvest (mm)	SGR (% day^{-1})	H_∞ (mm)	K	t_0	Days to reach 80 mm (VBGF projection)	K when $H_\infty = 120$
1 m[a]	80.66 ± 2.51	0.29	128.01 ± 21.52	1.00 ± 0.28	–0.44 ± 0.05	0	1.14
3.5 m[b]	78.01 ± 4.80	0.27	96.96 ± 17.58	1.83 ± 0.65	–0.34 ± 0.08	26	1.07
6 m[b]	77.10 ± 4.20	0.26	90.89 ± 8.98	2.02 ± 0.50	–0.35 ± 0.06	59	0.97

Common superscripts depict statistically homogenous von Bertalanffy growth functions (α = 0.05) determined by between-treatment likelihood ratio tests.

($X^2 = 2.272$, 2 *d.f.*, $P = 0.321$). The difference, however, was that the 1-m treatment produced the highest growth coefficient ($K = 1.14$), compared with 3.5-m ($K = 1.07$) and 6-m ($K = 0.97$) (Fig. 3, Table 2). Shell height gains for the 1-, 3.5-, and 6-m treatments were 35.9 ± 2.4, 32.7 ± 4.8, and 31.6 ± 3.7 mm, respectively, over the 201-day culture period representing mean specific growth rates of 0.29%, 0.27%, and 0.26% day^{-1}, respectively, (Table 2). Only scallops from the 1-m treatment attained a mean SH of 80 mm, the target size-at-harvest in this study. Projections of the VBGF estimated that scallops in the 3.5-m treatment would require a further 26 days of cultivation to reach 80 mm SH, whereas scallops in the 6-m treatment would require a further 59 days (Table 2). Mortality caused by transport was 12.59%. Catch curve analysis for the culture period estimated total mortality (Z) as 0.13, 0.21, and 0.28 for the 1-, 3.5-, and 6-m treatments, respectively (Fig. 4). Survival at 1-m (47% ± 12.5%) and 3.5-m (30% ± 9%) were not significantly different from each other ($X^2 = 1.64$, 1 *d.f.*, $P = 0.2$), but survival at 6-m (17% ± 4.5%) was significantly lower than at 1-m ($X^2 = 11.39$, 1 *d.f.*, $P = 0.001$) or 3.5-m ($X^2 = 5.79$, 1 *d.f.*, $P = 0.02$). The highest mortality occurred between the June (day 33) and August (day 90) sampling events which showed a proportional mortality of 32.6% ± 12.1%, 45.9% ± 4.0%, and 65.7% ± 12.6% at 1-, 3.5-, and 6-m, respectively.

Shell Biofouling Index

The shell biofouling index for scallops collected from the August mortality event was significantly higher in the 1-m treatment (36.45% ± 9.02%) compared with 3.5-m (33.55% ± 7.47%) and 6-m (25.65% ± 9.84%) ($F_{2,87} = 12.01$, $P < 0.001$).

Condition Indices

Soft tissue condition indices were similar in June and September but changed significantly in December (Fig. 5). In December, the gonadosomatic index doubled from 11.18% ± 3.58% in June to 22.32% ± 3.79% ($F_{2,88} = 85.75$, $P < 0.001$), whereas the adductor muscle index decreased from 44.86% ± 4.64% to 34.39% ± 3.58% ($F_{2,88} = 85.07$, $P < 0.001$) (Fig. 5). There was a statistically significant drop in the condition index for remaining tissue in September ($F_{2,88} = 3.67$, $P = 0.03$), but proportionally the contribution of these tissues changed only slightly (Fig. 5).

Economic Feasibility

Expenses

The total expenses that would be incurred before the generation of revenue at the end of the first year would be US $5,485.51 for the small farm and US$27,659.03 for the large farm. These figures represented the value of the bank loans necessary to initiate a scallop enterprise at existing fish monoculture rafts. Capital expenses in year 0 were US$4,573.21 and US$23,269.03 for the small and large farm (Table 3). The purchase of lantern nets represented the bulk of total capital expenses, 40.6% (US$1,856.00) for the small farm and 56.1% (US$13,056.00) for the large farm. Annual operating expenses were US$912.31 for the small farm and US$4,390.00 for the

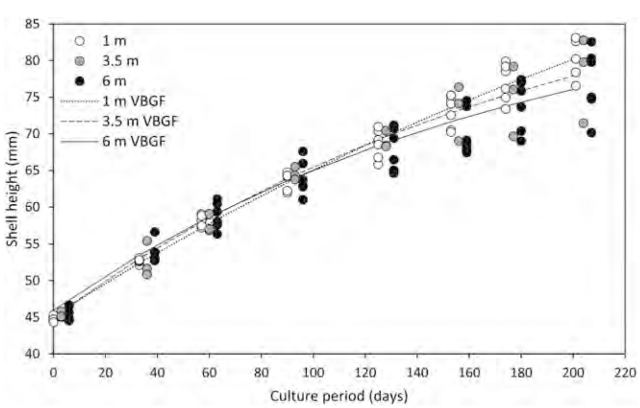

Figure 3. Observed and VBGF predicted height-at-time for *Mimachlamys nobilis* cultivated at the Kau Sai FCZ in Hong Kong for 201 days from May 29 to December 16, 2016.

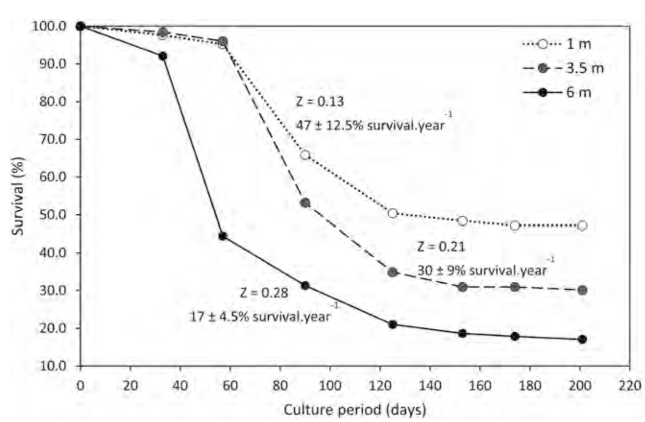

Figure 4. Survival (%) and corresponding instantaneous rate of total mortality (*Z*) for *Mimachlamys nobilis* cultivated at the Kau Sai FCZ, Hong Kong, for 201 days from May 29 to December 16, 2016.

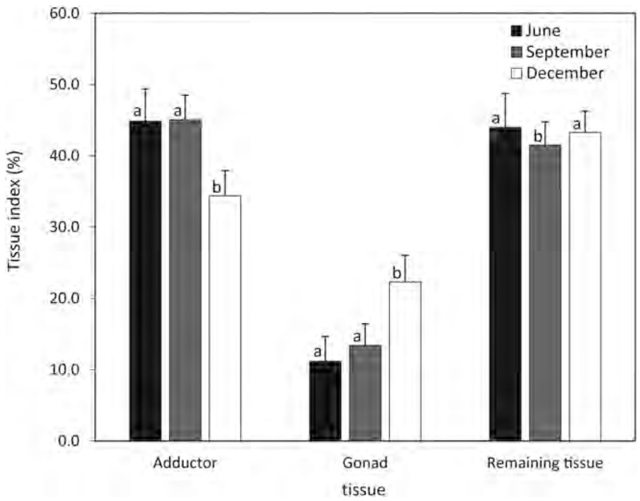

Figure 5. Adductor, gonadosomatic, and remaining soft tissue condition indices for *Mimachlamys nobilis* cultivated at the Kau Sai FCZ in Hong Kong for 201 days from May 29 to December 16, 2016. Common superscripts depict statistically homogenous results ($\alpha = 0.05$) determined by using one-way analysis of variance.

large farm in year 0 and increased to US$1,297.00 and US $6,241.00, respectively, in year 10 because of inflation (Table 4). The largest proportion of operating expenses consisted of labor which accounted for 67.9% (US$619.23) and 68.4% (US $3,003.85) of total operating expenses for the small and large farm, respectively. The largest labor expense on the small farm was the manpower required to support the annual harvest event (US$442.31, 48.5%) and on the large farm it was the manpower necessary to support the bimonthly replacement of lantern nets with an annual cost of US$1,990.38 (45.3%). As part of the assessment, the bank loans for the small and large farm, and their 5% annual interest, were paid off from year 1 to 5 at a rate of US$1,267.02 and US$6,388.54 per year, respectively.

Revenue

Revenue was generated from the end of year 1 following the first harvest. Annual harvest volumes were 1,680 catties (1,018 kg) and 11,900 catties (7,211 kg) for the small and large farm.

Bioeconomic Assessment

Cash flow projections from the 10-y simulation predicted positive results for both farm sizes (Fig. 6). The largest annual expenses were incurred in year 0 and year 6 because of the initial purchase of lantern nets and the need to replace them after 5 y of use (Fig. 6, Table 3). Gross revenue increased slightly over the 10-y period (Fig. 6). The 10-y NPV for the small farm was US $20,211.33, which represented a 52% IRR and a DPBT of 3 y. The 10-y NPV for the large farm was US$227,406.49, which represented a 103% IRR and a DPBT of 2 y. The sensitivity analysis of key variables showed that the NPV of the operations was robust to changes in seed price, minimum wage, lantern net price, mortality during transport, and growth rates (Fig. 7). The NPV were most sensitive to changes in total mortality during grow-out and changes in sales price. A 30% increase in the total mortality at the small farm was the only simulation that resulted in a negative NPV_{10} (Fig. 7).

DISCUSSION

Environmental Parameters

Water column stratification is commonly observed in inshore areas of the South China Sea through the midsummer monsoon season (Mao et al. 2011, Zhou et al. 2012). The temperature, salinity, and oxygen stratification observed at Kau Sai FCZ until mid-September is, therefore, typical for the region. The recession of stratification from mid-September onward was probably related to improved water column mixing during winter conditions (Yin 2002). The generally homogenous SPM and chlorophyll concentrations between treatment depths suggest that scallop food availability was similar between treatments, and so, food availability probably did not cause the observed differences in growth and mortality. Periodically higher chlorophyll concentrations were observed at 6 m compared with 1 and 3.5 m on days 27, 53, 110, and 153 (Fig. 2). This could have been caused by zooplankton feeding in the surface layers or the vertical migration of phytoplankton in the water column (Smayda 1997, Park et al. 2001, Tan et al. 2004). Monthly monitoring data from a government monitoring site approximately 1.5 km away from any fish farming showed that SPM ranged from 0.6 to 8.1 mg L^{-1} and chlorophyll-a ranged from 0.15 to 18 μg L^{-1} from May to December 2016 (Site PM9, EPD 2016). This is in line with the SPM concentrations of 0.35–7.07 mg L^{-1} and total chlorophyll concentrations of 0.40–12.81 μg L^{-1} from Kau Sai and suggests that fish farming activity did not affect these parameters at the culture zone. By December the minimum water temperature of 21.28°C was reached and coincided with the planned harvest (Fig. 2).

Growth and Mortality

High midsummer mortality has been accepted as a normal event during open water scallop grow-out in China (Guo et al. 1999, Xiao et al. 2005, Yu et al. 2010). In the present study, *Mimachlamys nobilis* showed good growth and low mortality in comparison with *Chlamys farreri*, the primary aquaculture scallop species in China. Xiao et al. (2005) farmed *C. farreri* through the peak of summer at three sites in Shandong and found that the SGR of *C. farreri* ranged from 0.15% to 0.91% day^{-1}, depending on the culture site and month. These results are comparable with the SGRs of *M. nobilis* which ranged from 0.26% to 0.29% day^{-1} at Kau Sai. The mortality of *C. farreri* reported by Xiao et al. (2005) was at least 85% at all sites, comparable with the 83% mortality of *M. nobilis* in the 6-m treatment. Total mortality of the 1-m *M. nobilis* treatment was substantially lower at only 53%.

The treatment-specific VBGF for *Mimachlamys nobilis* showed that the 1-m treatment exhibited significantly better growth than 3.5- or 6-m. It is well known that food availability can affect the growth of bivalves cultured in open water (Wong & Cheung 1999, Hawkins et al. 2002). In the present study, however, there was no apparent difference in SPM and chlorophyll concentrations between depth treatments which suggests that growth differences were probably not related to food supply. One possibility for the inferior growth in deeper water could have been the generally suboptimal environmental conditions at 3.5 and 6 m (Fig. 2). In particular, the periodically low oxygen concentrations could have imposed substantial physiological stress on *M. nobilis* in the 6-m treatment. Oxygen was generally

TABLE 3.

Capital, operating, and financial expenses associated with initiating integrated scallop *Mimachlamys nobilis* aquaculture at existing small (45 m^2) and large (315 m^2) fish monoculture rafts in Hong Kong.

Expense	Description	Unit	Lifespan (y)	Small farm		Large farm	
				Quantity	Total cost (USD)	Quantity	Total cost (USD)
Capital expenses (year 0)							
Equipment							
Lantern net (50 cm)	14-layer, 2-cm monofilament mesh	Nets	5	58	1,856.00	408	13,056.00
Lantern net droplines	Two 3-m droplines per net	Meters	3	348	89.23	2,448	627.69
Supplementary flotation	One float per two active nets	Floats	5	10	193.58	68	1,316.41
Scallop acclimation tanks	Incl. aeration hoses	Set	3	47	903.85	111	2,134.62
Scallops							
Scallop grow-out stock	520 scallops per box	Box	1	47	379.61	332	2,681.54
Scallop road freight	Supplier to pier	Truck	1	1	1,092.32	3	3,276.92
Scallop sea freight	Pier to farm	Boat	1	1	58.62	3	175.85
Total capital expenses		Farm	–	–	4,573.21	–	23,269.03
Operating expenses (year 0)							
Labor							
Scallop stocking	Acclimation and stocking over 1 day	Workers/day	–	4	176.92	21	928.85
Lantern net replacement	Bi-monthly; 20% of nets replaced per day	Workers/day	–	0	0.00	45	1,990.38
Lantern net cleaning	20% of nets cleaned per day	Workers/day	–	0	0.00	0	0.00
Harvesting and shell biofouling removal	Harvest period Small farm = 5 days Large farm = 10 days	Workers/day	–	10	442.31	20	884.62
Harvest							
Boat trip to deliver harvest	Small farm: 5 trips Large farm: 10 trips	Trips	–	5	293.08	10	586.15
Total operating expenses		Farm	–	–	912.31	–	4,390.00
Total operating + capital expenses		Farm	–	–	5,485.51	–	27,659.03
Financial expenses (year 1–5)							
Annual payment of 5-y bank loan	Paid off in year 1–5	Payments/year	–	1	1,267.02	1	6,388.54
Total financial expenses		Farm	–	–	1,267.02	–	6,388.54

TABLE 4.

Annual cash flow (USD '000) for a *Mimachlamys nobilis* farming operation integrated at existing small (45 m^2) and large (315 m^2) fish monoculture farms in Hong Kong.

	Small farm					Large farm				
Year	Capex	Opex	Finex	Net revenue	Net revenue (PV)	Capex	Opex	Finex	Net revenue	Net revenue (PV)
0	4.57	0.91	0.00	–5.49	–5.49	23.23	4.39	0	–27.66	–27.66
1	1.59	0.95	1.27	2.75	2.62	6.35	4.55	6.93	27.62	26.30
2	1.64	0.98	1.27	2.88	2.62	6.58	4.71	6.93	28.80	26.12
3	1.70	1.01	1.27	3.02	2.61	6.82	4.88	6.93	30.02	25.94
4	2.91	1.05	1.27	2.19	1.81	10.24	5.05	6.93	28.59	23.52
5	1.83	1.09	1.27	3.32	2.60	7.31	5.23	6.93	32.61	25.55
6	4.42	1.13	0.00	2.41	1.80	25.32	5.42	0	24.31	18.14
7	3.23	1.17	0.00	3.64	2.59	11.38	5.62	0	37.81	26.87
8	2.03	1.21	0.00	4.89	3.31	8.13	5.82	0	42.27	28.61
9	2.10	1.25	0.00	5.07	3.27	8.42	6.03	0	43.78	28.22
10	3.59	1.30	0.00	4.05	2.48	12.65	6.24	0	42.01	25.79

Capex, capital expenses; Opex, operating expenses; Finex, finance expenses. Values are not cumulative and are adjusted for a 3.58% annual inflation. A 15% profit tax has been deducted from the net revenue values. The present value (PV) of net revenue was calculated using a 5% discount rate.

lower at 6 m and reached a minimum of 1.73 mg L^{-1} in mid-July. Low oxygen concentrations at Kau Sai could have resulted from the resuspension of fine sediment during monsoons and microbial respiration in deeper water (Gao et al. 2006, Zhou et al. 2006). It is also likely that oxygen concentrations would have fallen even further at night during algal respiration. It is, therefore, possible that the culture environment for *M. nobilis* at 6 m was suboptimal. These findings have important implications for industry because the VBGF projections estimated that the 3.5- and 6-m scallop treatments would require up to two additional months to reach an 80 mm SH. The additional time required for grow-out would impose additional expenses on farmers and may necessitate the continued cultivation of *M. nobilis* through midwinter when water temperatures fall below the optimal range for *M. nobilis* grow-out, estimated at 20°C–25° C (Guo & Luo 2016).

In the present study there was a significant increase in the mortality of *Mimachlamys nobilis* with increasing depth from 1 to 6 m. Lodeiros et al. (1998) found that mortality in the tropical scallop *Lyropecten nodusus* (Linnaeus, 1758) was different between treatments at 8, 21, and 36 m and hypothesized that the differences were due to different growth environments between depths, leading to differences in temperature, reproductive stress, shell biofouling, and the density of toxic dinoflagellates. Lodeiros et al. (1998) concluded that the overall growth environment was different between depths. In the present study there were substantial differences in temperature, salinity, and oxygen between depths from May to September suggesting that the different growth and mortality between treatments was probably caused by different growth environments during midsummer. In particular, it is likely that the low oxygen concentrations at 3.5 and 6 m through midsummer was a leading cause of the higher mortality observed at those depths. One further mortality-related observation can be made; the inflow of fresh water during heavy summer monsoons did increase mortality at 1-m. This is relevant because the perception among fish farmers in Hong Kong is that it is not possible to farm sedentary species like *M. nobilis* because monsoon rain is likely to cause total stock loss. Previous experimental trials with *M. nobilis* have shown that the species is tolerant to a wide range of salinities from 24.3 to 37.2 (Zhang et al. 2008). Therefore, the high survival of *M. nobilis* at 1 m compared with those at 3.5 and 6 m shows that mortality was not unduly influenced by surface salinity flux.

The relatively high mortality of *Mimachlamys nobilis* observed during midsummer in all treatments was not associated with any abnormal mortality of the fish at any farms at Kau Sai. High midsummer mortality of scallops farmed in China was first observed in *Chlamys farreri* in 1994 and has been accepted as a normal part of husbandry (Guo et al. 1999, Xiao et al. 2005, Yu et al. 2010). No previous study has been able to pinpoint the causes of these annual mortality events but it has been hypothesized that they could result from a combination of generally adverse environmental conditions including high temperature, water body overuse, scallop raft overcrowding, reduced scallop immunity in summer, opportunistic predators or pathogens, and stress during reproduction (Zhang & Yang 1999, Xiao et al. 2005, Yu et al. 2010). The measures that have been recommended for minimizing annual mortality have included maintaining responsible stocking densities, maintaining healthy seed stock, extending culture to areas with depths greater than 20 m, and improving scallop germplasm, but the benefits of these measures remain undemonstrated at any large scale (Yang et al. 1999, Zhang & Yang 1999). Until further research can identify practical methods to minimize mortality, high stock losses in summer should be accepted as a normal part of *M. nobilis* husbandry and must be accounted for when calculating stock requirements to ensure that target harvests are met.

One of the potential benefits of integrating scallops with fed finfish is that by-products from fish feeding can increase scallop food availability which could lead to improved scallop growth (Stirling & Okumus 1995, Barrington et al. 2009). Dissolved inorganic nutrients released from fish can promote the proliferation of dietary microalgae and it is possible that scallops could directly assimilate uneaten fish feed or fish feces (Parsons et al. 2002, Sarà et al. 2009). Although the present study has shown the financial advantage of integrating *Mimachlamys*

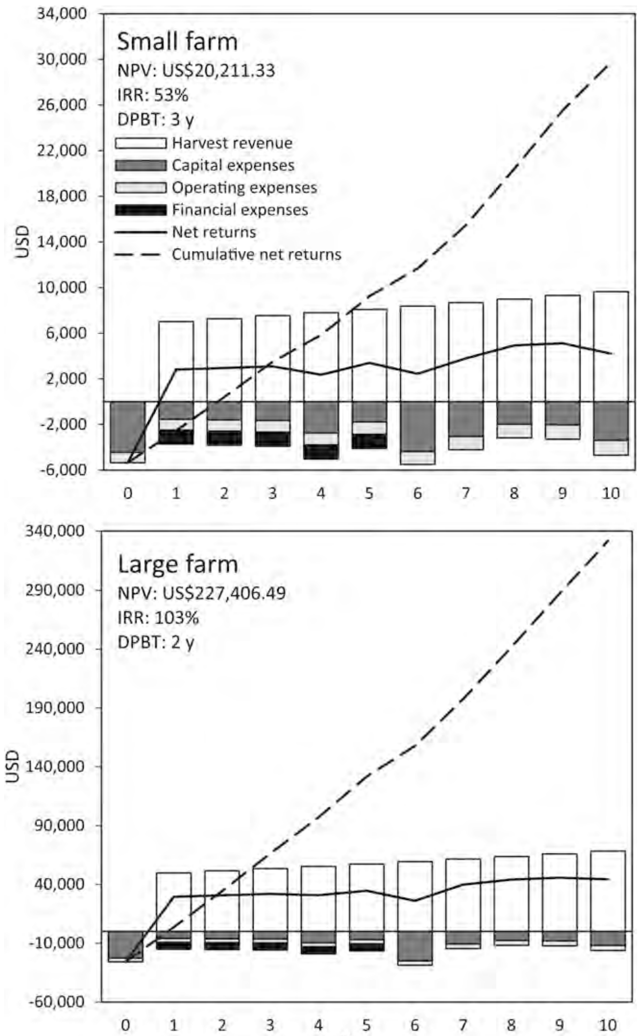

Figure 6. The 10-y cash flows (U.S. dollars), NPV, IRR, and DPBT results for the integration of the scallop *Mimachlamys nobilis* at existing small (45 m^2) and large (315 m^2) fish monoculture rafts in Hong Kong.

nobilis from the perspective of fish monoculture operations, future work should investigate any potential growth advantages to *M. nobilis* integrated at fish farms compared with *M. nobilis* produced at scallop monoculture sites. In addition, filter feeders are considered extractive species that may help to remediate some of the organic waste released from fish farms (Parsons et al. 2002, Cranford et al. 2013). Future work should attempt to quantify the bioremediation capabilities of *M. nobilis* for extracting the organic waste from suspended mariculture (Parsons et al. 2002).

Shell Biofouling Index

The settlement of fouling organisms on shells and culture gear is problematic because fouling can decrease growth and product marketability while increasing mortality and the labor required to process scallops before distribution (Watson et al. 2009, Adams et al. 2011, Qi et al. 2014). Previous work has shown that decreased growth and increased mortality occur when severe fouling inhibits food and oxygen supply, serves as a habitat for predatory invertebrates such as crabs, and acts as a vector for pathogens (Lesser et al. 1992, Freites et al. 2000, Wu et al. 2003, Sievers et al. 2013). In the present study, the 1-m treatment exhibited the highest level of biofouling but this was also the treatment that had the best growth and survival. This suggests that biofouling was not the root cause of the lower production performance observed at 6 m. The higher biofouling load in the 1-m treatment could be due to better environmental conditions in the upper water column, resulting in increased settlement success by fouling invertebrates (Claereboudt et al. 1994, Taylor et al. 2006). In the United States, fouling of cultured bivalves is accepted as part of normal husbandry—the average farm-level cost of biofouling was estimated by countrywide surveys at 14.7% of farm revenue (Adams et al. 2011). Expenditure went to husbandry efforts to reduce fouling and measures to remove fouling during processing. In this study, fouling was not a major financial concern for the small or large farm because it was removed as part of processing during harvest. Processing was handled by existing farm labor and the help of two part-time workers on each harvest day (Table 3). As fouling was not the cause of increased mortality, and was not associated with high costs, fouling can be accepted as part of *Mimachlamys nobilis* husbandry until cost-effective methods to eliminate fouling can be developed.

Condition Indices

The doubling of the gonadosomatic index of *Mimachlamys nobilis* in December, and the 25% decrease of the adductor index, coincided well with the planned harvest time. Gonad maturation with decreasing temperature has been reported for the bivalve *Atrina maura* (Sowerby, 1835) because lower temperatures facilitate a longer vitellogenic phase (Rodríguez-Jaramillo et al. 2001). The decrease in the proportional contribution of the adductor muscle observed in *M. nobilis* in December is typical in scallops because ripe gonads make a disproportionately large contribution to soft tissue indices and because of the high energy demands of gamete production (Pazos et al. 1997, Mendo et al. 2011). A full gonad is necessary to insure good product marketability in China and so the favorable soft tissue indices confirm that December is an appropriate month to harvest *M. nobilis* each year.

Economic Feasibility

This study showed that physically integrating *Mimachlamys nobilis* at existing fish rafts in Hong Kong is technically feasible because the scallops grew to optimal market size (80 mm SH) from June to December with sufficiently low mortality to warrant a comprehensive economic feasibility assessment. Cost calculations showed that it would cost US$5,485.51 to initiate scallop farming at a small fish farm (45 m^2) and US$27,659.03 at a large fish farm (315 m^2). The economic simulations showed that, despite high midsummer mortality, start-up capital could be recovered within 3 y (Fig. 6).

Expenses

The scallop farming enterprise benefitted from the existing infrastructure of the fish monoculture operation. Start-up expenditure was, therefore, low compared with studies that established entirely new operations (e.g., Choi et al. 2006, Taylor et al. 2006, Mendo et al. 2011). Ongoing annual operating expenses were also low because scallops do not

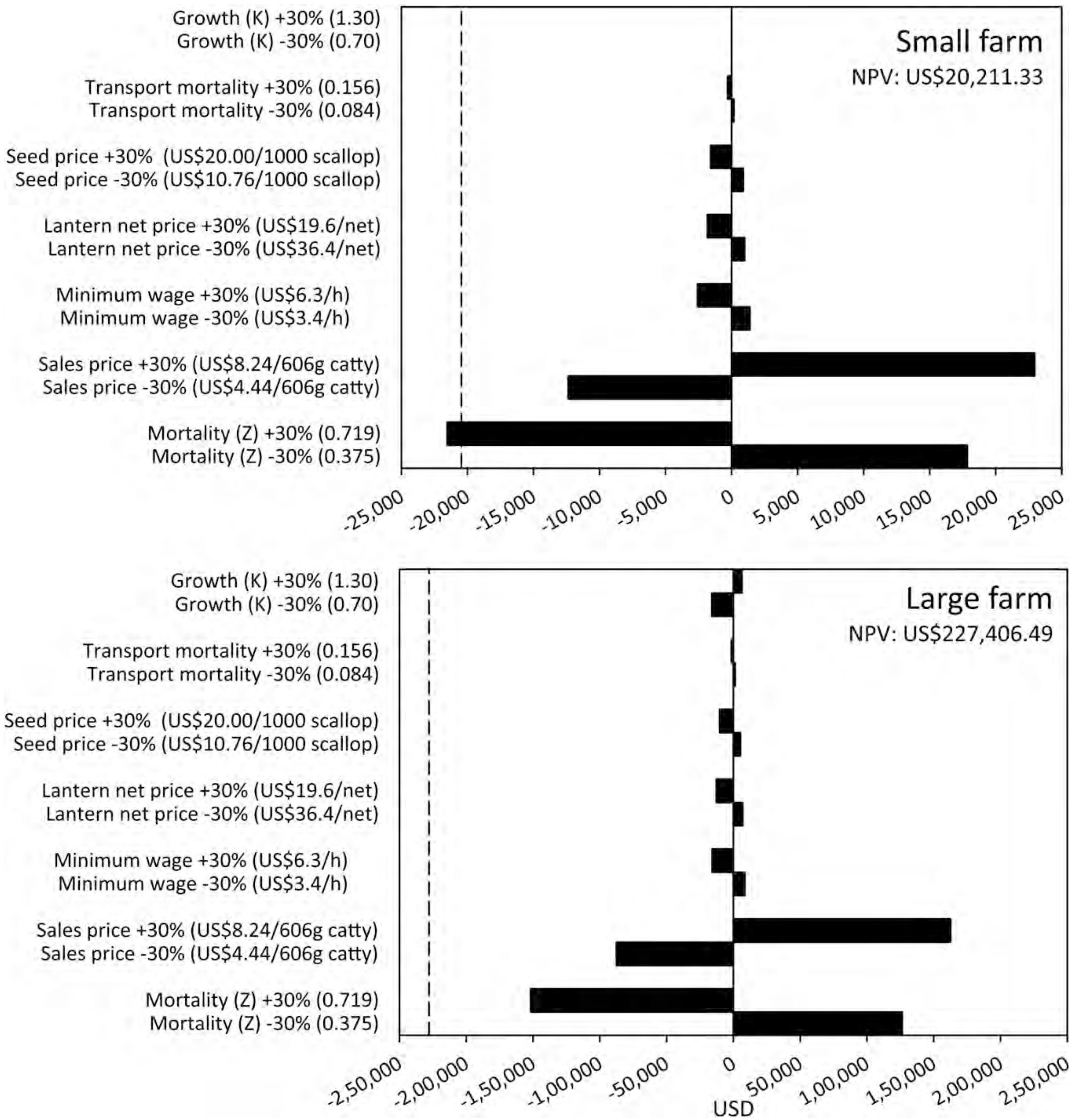

Figure 7. Sensitivity analysis of the U.S. dollar change in the NPV_{10} for a 10-y integrated *Mimachlamys nobilis* operation at existing fish monoculture farms in Hong Kong. The dashed line depicts the point at which the NPV_{10} would be negative.

require feed inputs. The requirements for supplementary labor were low because the most frequent husbandry activity was the routine replacement and cleaning of fouled lantern nets which needs to be performed bimonthly based on observed biofouling loads at Kau Sai FCZ. On the small farm, which integrated 48 active lantern nets, net cleaning and replacement could be covered by existing farm labor. On the large farm, 45 worker days were required per year to cover the additional labor associated with this task, representing a relatively small expense in comparison with the revenue generated (Table 3).

Revenue

From the end of year 1, the scallop enterprises generated positive net revenues with an annual present value ranging from $1,852.00 to $3,365.00 for the small farm and from $18,142.00 to $28,611.00 for the large farm (Table 4). These values represent a considerable annual increase in liquidity for relatively small-scale fish farms that are traditional, family-based operations. Given that the weight of the fish farmed in Hong Kong in 2014 accounted for only 2% of the weight of fish consumed, it is possible that the industry needs additional sources of income to help sustain fish farming operations and promote progress toward modern aquaculture (Lai et al. 2016). The additional revenue from an integrated scallop enterprise could help provide the capital necessary to achieve this. In addition, the simulations that were run in the present study did not increase the total scallop production volume over the 10-y assessment period. This was a precautionary measure because a scallop enterprise would be a first for Hong Kong and so the effects of more intensive production are not predictable (Shi et al. 2013). In future work there is scope for expansion. The apparent increase in gross revenue over the 10 y resulted from the 3.58% inflation rate.

Bioeconomic Assessment

Existing farm infrastructure and labor substantially reduced the expenditure necessary to initiate a scallop enterprise and so simulations returned favorable NPV and IRR values, and short DPBT. Over the 10-y operation, the largest expenses were incurred in year 0 and year 6 because of the initial purchase and subsequent replacement of scallop lantern nets at the end of their useful life.

The positive NPV for both farms suggests that it is worth proceeding with integrated scallop farming at existing fish monoculture rafts in Hong Kong and so further research and development is warranted (Engle 2010, Di Trapani et al. 2014). This is supported by the high IRR which indicates that scallop operations would be profitable because IRR values are substantially higher than the opportunity cost of capital, typically taken as 10% (Engle 2010). The IRR of 52% for the small farm and 103% for the large farm are higher than the IRR calculated in similar scallop production studies. Penney and Mills (2000) reported IRR from –9.9% to 39.4% for a *Placopecten magellanicus* (Gmelin, 1791) operation in Newfoundland, Canada. Taylor et al. (2006) reported IRR of 21.6%–27.0% for the scallop *Nodipecten subnodosus* (Sowerby, 1835) cultivated on the Baja California Peninsula. The comparatively lower IRR from these studies is probably because they had to construct their culture systems without existing infrastructure or labor. The DPBT estimated that the time to recoup the initial investments was 3 y for the small farm and 2 y for large farm, about half the time required to recoup the initial investment in an *Atrina maura* farm in Mexico which was estimated at 6–7 y (Mendo et al. 2011). The shorter DPBT of the large farm compared with the small farm is due to economies of scale; there is a proportionate saving in costs gained from an increased level of production. The large farm is approximately seven times larger than the small farm but has an NPV that is approximately 10 times higher. Economies of scale is common in aquaculture and has been demonstrated previously for bivalves (Penney & Mills 2000, Mendo et al. 2011).

The sensitivity analysis showed that the scallop enterprise was robust to changes in lantern net price, seed stock price, transport mortality, and growth rates but was somewhat sensitive to changes in mortality and market price (Fig. 7). Changes in growth rate made no apparent change to the NPV of the small farm and had only a slight influence on the NPV of the large farm. The month-to-month husbandry expenses for *Mimachlamys nobilis* are small in comparison with the revenue generated and so a potential decrease in growth rates, that would extend the culture duration, would change the NPV only slightly. It is important, however, to consider that the water temperature after December usually drops below the optimal conditions for *M. nobilis* growth which may extend the necessary culture duration further still. The *M. nobilis* enterprises were robust to changes in the minimum wage because the additional labor requirements of the scallop operations were small. Changes to transport mortality and the price of grow-out seed stock had a very small impact on the NPV because the annual purchase of seed, and the transport of that seed, made little contribution to the overall cost of the business (Table 3). In the event of considerably higher mortality during transport, it would be cost-effective to add more seed to a shipment, or to order an additional shipment of seed, to mitigate any large mortality events that may occur during transport. Despite the high capital cost of the lantern nets, and their large contribution to cash outflow in year 0 and year 6, the operation was relatively robust to changes in lantern net price because the depreciation of the nets was spread across the full 5 y of useful life. The 10-y NPV was most sensitive to changes in sales price and mortality, probably because these parameters directly impacted the bottom line of the enterprise. This is a common finding in aquaculture businesses that are dependent on producing a critical biomass to insure farm profitability (Stirling & Okumus 1995, Taylor et al. 2006, Fonseca et al. 2017). A 30% increase in mortality over the 10-y simulation of the small farm was the only variation that resulted in a negative NPV. In any farm situation a 30% increase in mortality would be critical. In this study, however, the existing farm infrastructure absorbed some of the major costs of the scallop enterprise which helped to buffer the impact of mortality. Still, it should be noted that the scallop systems were somewhat sensitive to changes in mortality which is an important consideration when assessing whether to proceed with integrated scallop farming. This is relevant to the present study because relatively small changes in depth from 1 to 6 m caused a significant increase in mortality and the causes of mortality cannot be easily controlled. There are, however, measures which could be taken to minimize the financial risks associated with mortality. One possibility would be to increase the initial stocking density from 32 scallops/layer (33% surface area), which was used in the economic assessment based on anticipated mortality and the target harvest volumes, to 42 scallops/layer (45% surface area), which was used in the field trial. Future work could look to increase scallop stocking densities as high as 60%–80%. These higher densities are commonly used in scallop farming in China and could offer some insurance against midsummer and depth-related mortality given the low cost of scallop seed and the low sensitivity of these operations to changes in seed price (Fig. 7). If higher than anticipated mortality occurs, then the higher stocking density would help to buffer losses. If higher mortality does not occur, then farmers could opt to redistribute surplus scallops to nearby farms, sell surplus scallops at suboptimal sizes, accept potentially reduced growth rates from overcrowding, or cull surplus scallops.

CONCLUSIONS

This baseline study has shown that physically integrating *Mimachlamys nobilis* at existing fish monoculture farms in Hong Kong is technically and economically feasible. Despite the low stocking densities used as a precautionary measure in the field trial, the bioeconomic assessment showed that the operations were profitable because *M. nobilis* grew well and showed sufficient survival to size-at-harvest. The different growth and mortality observed between depth treatments suggests that changes in the growth environment from 1 to 6 m could significantly impact production. As the fish rafts in Hong Kong have operated under a monoculture model for more than 50 y, the alternative to an integrated scallop enterprise would be the "do nothing" option. Integrated scallop farming is, therefore, recommended because the simulations of 10-y operations produced high NPV and IRR, and short DPBT for the two farm sizes assessed. The sensitivity analysis showed that the proposed scallop enterprises were robust to changes in most key variables and were moderately sensitive to changes in sales price and stock mortality. On the one hand the sensitivity analysis identified that there is some inherent risk in the proposed scallop operation because changes to sales price and stock mortality cannot be easily controlled. On the other, integrating scallops would add a new trophic level to farm operations that would help to increase farm output and diversify production, thereby reducing risk at the farm level.

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附件(3.1) 棄置育苗器的程序

漁農自然護理署

九龍長沙灣道三〇三號
長沙灣政府合署八樓

AGRICULTURE, FISHERIES AND CONSERVATION DEPARTMENT

8/F, Cheung Sha Wan Government Offices
303 Cheung Sha Wan Road
Kowloon, Hong Kong

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香港九龍塘達之路 83 號香港城市大學
楊建文學術樓 P5840 室
海洋污染國家重點實驗室　香港城市大學
[redacted]

[redacted]

「漁業持續發展基金」
申請編號：SFDF-0016
項目：魚排上建立示範及教育單位，展示商業上可行的
循環海水育苗系統
<u>提早完結項目及棄置項目資產育苗器事宜</u>

本署已於2021年4月26日收悉貴機構就題述項目申請提早完結及處理項目資產。其後，經本署與貴機構溝通後認為項目仍須完成部分成果而無需申請提早完結。就有關棄置育苗器申請，現通知貴機構，署方原則上批准有關申請。

請按照貴機構的既定程序處理育苗器的棄置事宜，並保留所有相關文件及於正式棄置育苗器前提交有關文件副本予本署以作記錄，而相關收入須存入為題述項目開立的獨立項目碼 (Unique Account Code) 的帳目。貴機構應遵守由漁護署及諮詢委員會訂定的採購規定(基金申請指引)及廉政公署所編製的《防貪錦囊－「誠信・問責」－政府基金資助計劃受資助機構實務手冊》內所載的指引。若資產登記冊內資產有任何變更(包括棄置），貴機構須即時更新登記冊並通知署方。

請貴機構儘快處理育苗器的棄置事宜，避免育苗器因結構受損而對養魚區內其他魚排或行經船隻造成危險。

如有任何疑問，請致電2150 7158與秘書處聯絡。

漁農自然護理署署長

（[redacted] 代行）

2021年7月6日

附件(3.2) 棄置育苗器的程序

By fax only

INVITATION TO TENDER

Tender Ref: **IT21/094AY** (*Please quote our ref in all correspondence.*)

15 October 2021

香港城市大學
City University of Hong Kong

Dear Sirs

Removal and Disposal of the Fire-damaged Fish Fry Chamber at Lo Tik Wan Lamma Island
(招標承投清除及移走位於南丫島蘆荻灣海上之育苗箱構築物及其他物件服務工程)

You are hereby invited to tender for the captioned in accordance with the terms and conditions of the Tender Documents as attached.

The tender shall be sent either by fax to 3442 0101 (which is designated for tender, and other fax number will not be accepted) or deposited in the tender box situated at the entrance of Finance Office, 4/F, Li Dak Sum Yip Yio Chin Academic Building, City University of Hong Kong, Kowloon Tong, Hong Kong, **not later than 2:00 pm, Tuesday, 26 October 2021.** However, you are encouraged to make the fax AND submit the tender in the Tender Box, as fax transmission may sometimes be unreliable that we would consider no tender submitted if no fax received at our fax server. Please note that City University of Hong Kong (CityU) will not be responsible for any loss or delay of your tender sent by post. ***Late tenders will not be accepted.*** In case of any dispute on the tender and its submission, CityU shall have the discretion to determine to accept the tender or not. The opening hours of our Procurement Unit of the Finance Office are:-

Monday - Friday : 9:00 a.m. - 12:30 p.m.
1:30 p.m. - 5:50 p.m.

In the event of a typhoon signal No. 8 or above or black rainstorm warning is hoisted on the date of return of tender, the closing time will be postponed to the same time on the next working day.

The Tender Documents comprise of:		Total no. of pages
	1. Schedule & Offer	3
	2. Specification & Appendix A	5
	3. Terms of Tender & General Conditions of Contract	3

The University reserves the right not to accept the lowest or any tender or any part of any tender. If a tender is submitted on the basis of overall acceptance of all the items offered, this must be clearly stated in the tender.

Tenderers are reminded that offering or giving any gratuity, bonus, discount, bribe, loan or any other gift or consideration as an inducement or reward to any employee or agent of the University in relation to this or any other University contract could constitute an offence contrary to the Prevention of Bribery Ordinance Cap. 201. If the tenderers were found to have made such an offer the University shall be at liberty to cancel the contract and shall hold the contractor liable for any loss or damages which the University may thereby sustain.

If you do not wish to tender, please inform us in writing before the Tender closing date. Please note that if you do not receive an acceptance notice from the University on or after the expiry of the tender validity, you should assume that your tender is unsuccessful.

You are required to attend a Site Visit at 14:00 on 20 Oct 2021 (Wednesday). Please be present at A pier near Ap Lei Chau Hung Shing Temple (鴨脷洲洪聖街鴨脷洲三號梯台). https://maps.app.goo.gl/GmjFuMLmd1ZWVC8f9

Should you require further clarification/information, please submit your questions in writing by fax to 3442 0102 on or before **12:00 noon 20 October 2021 (Wednesday)**. University will have no obligation to provide answers to request for clarification received after this date.

For technical details, please contact [redacted] of State Key Laboratory of Marine Pollution. For general enquiries, please contact the undersigned at 3442 6345 or [redacted] of Finance Office at 3442 6367.

Yours faithfully

[redacted]

for Secretary to General Tender Board

To: The Secretary to General Tender Board
City University of Hong Kong
Finance Office
4/F, Li Dak Sum Yip Yio Chin Academic Building
Tat Chee Avenue, Kowloon
Hong Kong
(Fax No. for submitting Tender: ***3442 0101***)

Invitation to Tender
Tender Ref.: **IT21/094AY**

Date: 11 October 2021

(Tender Closing Date:
2:00 p.m., Tuesday, 26 October 2021)

Schedule & Offer

We have studied the Terms of Tender, General Conditions of Contract and the Special Conditions of Contract (if any) and do hereby agree to supply all or any portion of the articles and services mentioned in the Tender as amended by us, which may be ordered by City University of Hong Kong, at the price quoted in the Tender, for delivery on or before the date mentioned in the Tender of where placed by City University of Hong Kong free of all other charges subject to and in accordance with the Terms of Tender attached hereto.

Item	Description	Quantity	Unit Rate (DDP) HK$	Total Amount (DDP) HK$
1.	**Removal and Disposal of the Fire-damaged Fish Fry Chamber** Dimension: 21m x 7m x 5m (LxWxH) Location: Lo Tik Wan, Lamma Island **<u>Requirements</u>** (1) Contractor should provide all necessary tools, materials and labour to removal, disassemble and disposal of a fire-damaged fish fry chamber with dimension: 21m x 7m x 5m (LxWxH) located at Lo Tik Wan, Lamma Island. Please refer to photos as attached Appendix A (4 pages) for information. (2) The contractor should be responsible to provide public liability insurance coverage. (3) The contractor should be responsible to provide employees' compensation insurance coverage for those employed for the execution of the works under this contract. (4) The contractor is responsible to clear and remove all rubbish/debris incurred from Site to locations, as agreed by the CityU, at his own expenses. (5) The contractor is required to control the disposal of public fill, construction and demolition waste to designated public filling facilities and landfills respectively, all illegal dumping of waste is not accepted. (6) Allow for any other items which have not been specifically measured above but are required for the completion of the works in accordance with the requirements and statutory requirements.	1 Job		

Schedule & Offer (Cont'd)

Item	Description	Quantity	Unit Rate (DDP) HK$	Total Amount (DDP) HK$
	Removal and Disposal of the Fire-damaged Fish Fry Chamber Dimension: 21m x 7m x 5m (LxWxH) Location: Lo Tik Wan, Lamma Island (7) All Government Fee and disposal regulation are according to Chapter 354 - Waste Disposal Ordinance. For the Fish Fry Chamber details, please refer to the attached Specification (1 Page) and Appendix A (4 Pages).			

Company Name and Chop: ______________________________ Date:______________________________

Schedule & Offer (Cont'd)

	The following **MUST BE** completed by Tenderer:-
a.	Time for completion of job: _________ days from placing of order.
b.	All services provided should comply with the Government Approved Regulations and Standards. **(YES/NO)***
c.	Payment term: 30 days net after acceptance of goods/services and against invoice. **(YES/NO)***
	*** Please delete as inappropriate**

Note to Tenderers

1. City University of Hong Kong reserves the right not to accept the lowest or any tender or any part of any tender. If a tender is submitted on the basis of overall acceptance of all the items offered, this must be clearly stated in the tender.
2. Should you require further clarifications on the Specification, please contact [redacted] State Key Laboratory of Marine Pollution). Any other questions relating to the submission of this tender, please contact [redacted].
3. Please return this page by fax with signature & company chop and indicate "No Offer" on it if you are unable to supply the above product. Please also state reason of "No Offer".

☞ **If you do not receive acceptance notice from the University on or after the expiry of the tender validity, you should assume that your tender is unsuccessful.**

Remarks:	Supplier's Reply
Tender remains valid for acceptance within 90 days after the closing date.	We offer to supply the goods at the price stated in accordance with the specifications and conditions above.
[redacted] _______________ *for* Secretary to General Tender Board	Signature ______________ Name ______________ Title ______________ Date ______________ Co. Name ______________ Co. Chop ______________ Telephone No. ______________ Fax No. ______________

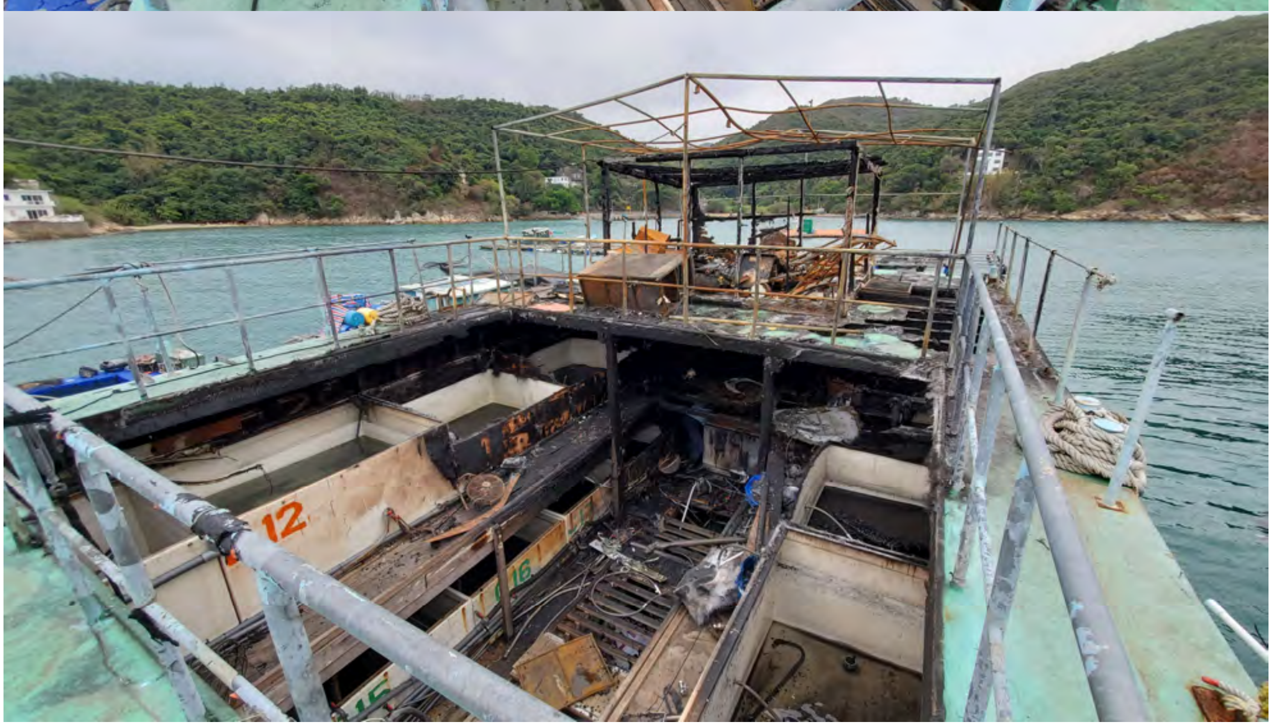
Invitation to Tender for the Removal and Disposal of the Fire-damaged Fish Fry Chamber at Lo Tik Wan Lamma Island
(項目: 招標承投清除及移走位於北南丫島蘆荻灣海上之育苗箱構築物及其他物件服務工程)

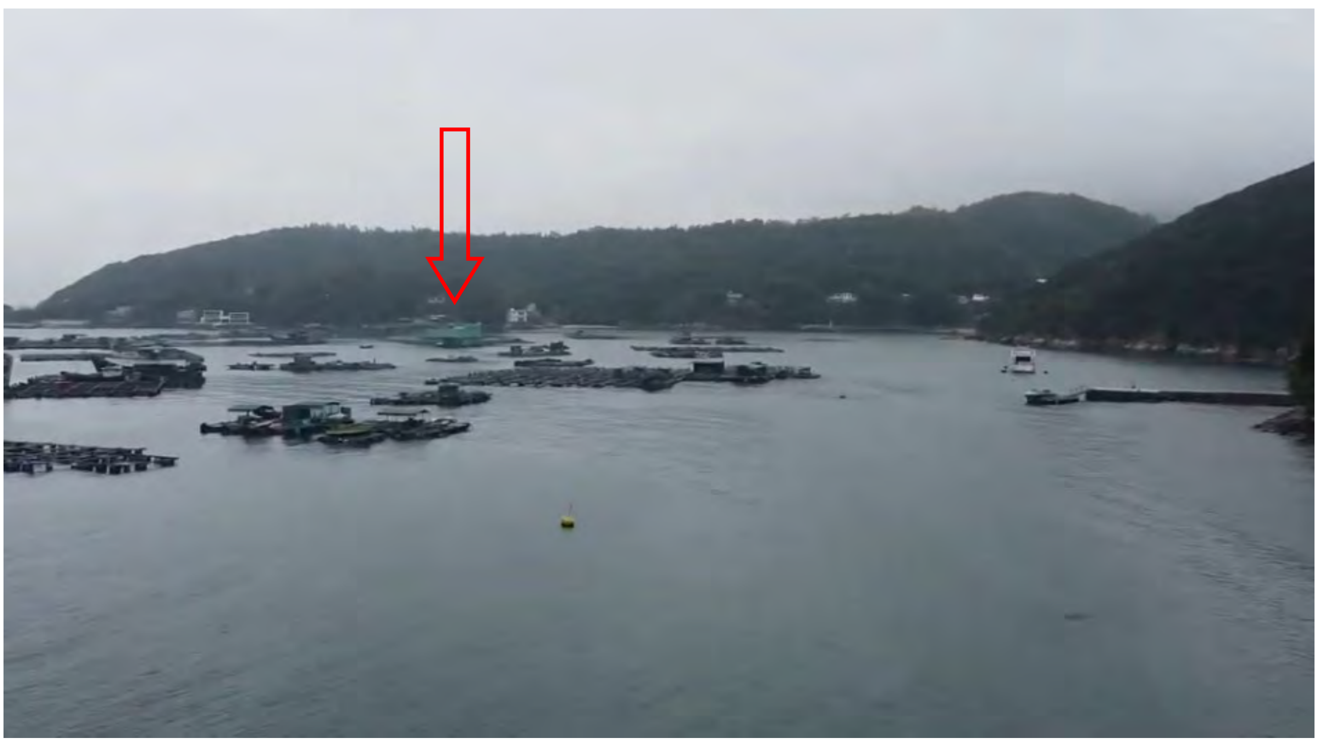
Details of the "Fish Fry Chamber"

主力結構: 此育苗箱主力結構參照木及玻璃纖維船的構造作基礎而建造，用以抵禦海浪及各種惡劣天氣環境，結構外皮（又稱船旁)水下用樟木，出水用非洲坤甸木。

育苗箱結構及資料如下:

1. 結構由兩條底骨（即龍骨) 12 吋 x 11 吋山樟木構造而成
2. 橫柴底陣即龍骨向左右伸延的支架約三吋半厚以及橫柴高度八吋厚
3. 橫柴樓頭三吋半厚，高度為七吋厚
4. 底旁用山樟木兩吋厚，出水用坤甸木兩吋厚
5. 波橋用抄木三吋厚，前後櫃面用坤甸木
6. 擋板用坤甸木，內掃一層防蟲蛀的保護油層(又稱黑鬼油)
7. 櫃陣內坑用坤甸木三吋半厚，高為五吋厚
8. 結構外皮(船旁)間兩個橫柴收螺絲
9. 結構內榜板加有孖釘
10. 育苗相結構內玻璃纖維育苗缸的建造數量不少於 30 個，每個約長三米 x 闊 2.5 米 x 高 1 米
11. 內部裝有兩部≥20kW 發電機及育苗箱內相關防水電力裝置,溫度調節和抽氣通風系統，包括內外所有電線及插頭。
12. 不少於五條錨鏈之繫泊設施





Terms of Tender

1. Except where the contract otherwise requires the following expressions in this form and the General Conditions of Contracts shall have the following meanings:
'Tenderer' means the Person or persons and/or the firm or the Company whose name appears in the quotation attached;
'Contractor' means the Tenderer whose tender is accepted as hereinafter provided;
'Receiving Officer' means the officer in charge of a department of the City University of Hong Kong to which any scheduled goods are to be sent and services are to be provided; or such other officer as he may be authorized to accept delivery thereof;
'Scheduled Goods' means the articles, materials or services referred to in the Schedule contained in the quotation attached;
'Contractual period' means the period specified in the quotation;
'Contract' means the contract hereunder and reference to the terms thereof shall include the terms of tender overleaf unless inconsistent with the context of such reference.

2. All goods or services not otherwise specified shall be in accordance with British Standard Specifications or equivalent where such exist.

3. Tenders shall, unless otherwise indicated by City University of Hong Kong, remain open for 90 days after the closing date.

4. The quantity shown against each item in the Schedule is an estimate of probable requirements and such estimate must be regarded as being given for the assistance of the Contractor on the best evidence available and not as being a figure to which the City University of Hong Kong binds itself to adhere. Any brand name shown is indicative and for reference purpose only, alternative offer of equivalent products will be considered.

5. Tenderers who do not receive a notification within seven days of the expiration of the ninety days mentioned in clause 3 above should assume that their respective tenders have not been accepted.

(a) All samples submitted for consideration must be collected by unsuccessful Tenderers within 7 days of the expiration of the ninety days mentioned in clause 3 hereof. If at the expiration of such seven days no arrangements have been made with City University of Hong Kong for the collection of such samples the Tenderer shall be deemed to have given up all title thereto and City University of Hong Kong may dispose of the same as it thinks fit without being responsible to the Tenderer in respect thereof.

(b) Receipts must be obtained for the deposit of samples with City University of Hong Kong and such samples need not be returned unless such receipt is produced at the time of collection.

Finance Office (Procurement Unit)

GENERAL TERMS AND CONDITIONS FOR GOODS AND/OR SERVICES

1. DEFINITIONS

Unless the context otherwise requires, the following terms have the following meanings:

(a) **"CityU"** means City University of Hong Kong;

(b) **"Contract"** means the contract between CityU and the Supplier for the supply of Goods and/or Services comprising the Purchase Order and the terms and conditions;

(c) **"Deliverables"** means any document or product that is to be delivered to CityU by the Supplier in the course of providing the Services, including (without limitation) any such product or document that is described as such in the Purchase Order;

(d) **"Delivery Location"** means the location(s) for the supply of the Goods and/or Services set out in the Purchase Order;

(e) **"Goods"** means the goods to be provided as described in the Purchase Order;

(f) **"Intellectual Property Rights"** means all present and future rights conferred by statute, common law or equity in any territory in or in relation to copyright and related rights, moral rights, trademarks, designs rig, patents, circuit layouts, business and domain names and all applications (and rights to apply) therefor;

(g) **"Purchase Order"** means the purchase order to which these terms and conditions are attached;

(h) **"Premises"** means any premises occupied by CityU;

(i) **"Purchase Price"** means the prices for the Goods and/or the charges for the Services set out in the Purchase Order;

(j) **"Services"** means the services to be provided as described in the Purchase Order;

(k) **"Supplier"** means the person or firm specified in the Purchase Order from whom CityU purchases the Good and/or Services;

(l) **"Supplier Personnel"** means all employees, agents, suppliers, contractors, and subcontractors of the Supplier who are involved in the provision of Services or the supply of Goods;

(m) **"Warranty Period"** means a period of twelve months after the acceptance of the Goods, Services and/or Deliverables or such other period as specified in the Purchase Order.

2. GENERAL

2.1 The Purchase Order constitutes an acceptance by CityU of the quotation or offer provided by the Supplier. The acknowledgement or execution of the Purchase Order or by performance of the Services or supply of the Goods set out therein shall mean Supplier's acceptance of all the terms and conditions of the Contract.

2.2 The Purchase Order once accepted, combined with these terms and conditions and/or any attachment expressly incorporated in writing shall be deemed to bind the Supplier to the Contract.

2.3 No variation, waiver, modification, deletion or addition to the terms and conditions of the Purchase Order shall be binding upon the parties unless approved in writing by CityU and attached to this Purchase Order.

2.4 The Purchase Order is not exclusive and CityU shall not be restricted from purchasing services similar to and/or identical to the Services or goods similar to the Goods from any third parties.

2.5 The Supplier shall not assign, transfer, subcontract or deal in any other manner with all or any of its right or obligations under the Purchase Order without the prior written consent of CityU.

3. SUPPLIER'S WARRANTIES

The Supplier represents and warrants:

(a) it has full clear title, rights, licences, interests and property necessary to provide the Goods, Deliverables and/or perform the Services;

(b) it shall comply (and shall procure that all Supplier Personnel shall comply) with all applicable laws in relation to the provision of the Goods, Services and/or Deliverables;

(c) it shall ensure that any Goods, Services and/or Deliverables shall be:

i. of the specific quality indicated in the Purchase Order;

ii. of merchantable and satisfactory quality;

iii. fit for any purpose held out by the Supplier or made known to the Supplier or intended by CityU;

iv. in conformance with any samples provided to CityU;

(d) the Goods, Services and/or Deliverables are to be guaranteed against faulty workmanship and faulty materials and remain so for the Warranty Period. All repairs and replacements within the Warranty Period shall be carried out free of charge by the Supplier;

(e) it shall not make any payment or offer anything of value, or request, or accept a financial or other advantage either directly or indirectly, where such payment, offer, or request could be or may be considered to have the purpose or effect of public or commercial bribery or to constitute the acceptance of, corruption, extortion, kickbacks, or other unlawful means of obtaining business.

4. DELIVERY, INSPECTION AND ACCEPTANCE OF GOODS AND DELIVERABLES

4.1 The Purchase Price set out in the Purchase Order includes packaging and delivery. The Supplier shall be responsible for and shall bear the cost of unloading all Goods and/or Deliverables to the Delivery Location or Delivery Locations as instructed by CityU from time to time.

4.2 The Supplier shall use suitable packaging and delivery method to ensure the Goods and/or Deliverables are delivered in good condition without damage; Time is of the essence with respect to the Supplier's delivery obligations under the Contract, or if no such time period is specified, the Supplier shall deliver the Goods and/or Deliverables on the date of the specified in the Purchase Order.

4.3 Each delivery of the Goods and/or Deliverables is accompanied by a delivery note which shows the date of the Purchase Order, the Purchase Order number, the type and quantity of the Goods and/or Deliverables including the code number of the Goods and/or Deliverables (where applicable), special storage instructions (if any) and, if the Goods and/or Deliverables are being delivered by instalments, the outstanding balance of Goods and/or Deliverables to be delivered.

4.4 (a) All deliveries of the Goods and/or Deliverables are subject to inspection and test by CityU and accordingly shall not be regarded as accepted. If the Goods and/or Deliverables are found not in accordance with any of the details shown in the Purchase Order, CityU reserves the right to reject and return the Goods and/or Deliverables to the Supplier at Supplier's expense;

(b) within twenty-four (24) hours of being notified in writing of the rejection of any goods delivered the Supplier shall remove the same;

(c) within seven (7) days of notification of rejection, the Supplier shall replace such goods with satisfactory goods specified in the Purchase Order or in the case where replacement goods have to be obtained from such sources outside Hong Kong, the Supplier must advise CityU the delivery date when replacement goods will be delivered unless with the notification of rejection, CityU shall have notified the Supplier that he does not require the replacement of such goods. CityU reserves the right to apply clause 10 in the event that replacement delivery cannot be made within the seven (7) days period referred to above whether or not replacement goods have to be obtained from sources outside Hong Kong or otherwise;

(d) the decision of CityU of rejection shall be final;

(e) if it shall prove to the satisfaction of CityU that the Supplier has offered for delivery any goods which have previously been rejected by CityU, CityU shall thereupon be at liberty to terminate this Contract in clause 10 of this Contract.

4.5 If the Goods and/or Deliverables are delivered in excess of the quantities ordered, CityU shall not be bound to pay for the excess and any excess shall be and shall remain at the Supplier's risk and shall be returned at the Supplier's expense.

4.6 The Supplier shall not deliver the Goods and/or Deliverables in instalments without CityU's prior written consent. Where it is agreed that the Goods and/or Deliverables are delivered by instalments, they may be invoiced and paid for separately.

4.7 Title and risk of the Goods and/or Deliverables delivered by the Supplier to the Premises in connection with the Purchase Order shall pass to CityU on satisfactory completion of delivery.

4.8 CityU shall be entitled at any time to defer the date of delivery of the Goods and/or Deliverables or the date for performance of the Services. Any such deferment shall not give rise to any legal right of action of any kind whatsoever on the part of the Supplier.

4.9 Without prejudice to any other provisions in the Contract, the Supplier agrees that it shall be responsible for making good with all possible speed at its own expenses any defect in or damage to any portion of the Goods and/or Deliverables which may develop during the Warranty Period, for that portion which results in a failure of the Goods and/or Deliverables to fulfil the specification or function or to meet the level of performance detailed in the Contract or arises from either defective materials, including software, workmanship or design or any act or omission of the Supplier during the Warranty Period.

4.10 If the Supplier in his tender has requested the return of empties to him he shall be entitled unless otherwise provided for under the Contract, to collect the same at any time after the expiration of twenty-eight (28) days from the date of delivery (or such earlier date as may be arranged with CityU) at his own cost and CityU shall not be liable in any way in respect of the loss of damage or such empties whilst under their control.

4.11 Any drawings and specifications reasonably required for the Supplier's guidance in the execution of this Contract shall be furnished free of charge but shall be returned on completion of the Contract. Supplier shall hold all materials, equipment and tools, drawings, specifications and data supplied by CityU to the Supplier ("Customer Materials") in safe custody at his own risk, maintain the Customer Materials in good condition until returned to CityU, and not dispose or use the Customer Materials other than in accordance with CityU's written instructions or authorization.

4.12 If required the Supplier shall furnish CityU with a proof note or certificate showing that the Goods and/or Deliverables have been subjected to the normal tests for such Goods or such tests as CityU may reasonably require.

5. DELIVERY AND ACCEPTANCE OF SERVICES

In the performance of the Services the Supplier warrants to CityU that the Supplier shall:

(a) complete the Services to the satisfaction of CityU within the period or on the date(s) specified in the Purchase Order and time is of the essence with respect to the Supplier's delivery obligations under the Contract;

(b) co-operate with CityU in all matters relating to the Services, and comply with all reasonable instructions and relevant policies and procedures of CityU;

(c) use Supplier Personnel who are suitably skilled, experienced and qualified for the roles; and in sufficient number to ensure that the Supplier's obligation are fulfilled in accordance with the Contract;

(d) ensure that the Services shall conform with all descriptions and specifications set out in the specification of the Service, and that the Deliverables shall be fit for any purpose expressly or impliedly made known to the Supplier by CityU;

(e) use the best quality goods, materials, standards and techniques, and ensure that the Deliverables, and all goods and materials supplied and used in the Services shall be free from defects in workmanship, installation and design;

(f) ensure that the Services are performed with due diligence, reasonable skill and care and in accordance with best industry practice at all times;

(g) when performing Services at any Premises, the Supplier shall minimise disruption to the normal operations of CityU and comply with the instructions given by CityU's representatives at the Premises;

(h) provide all equipment, tools and vehicles and such other items which are required to provide the Services;

(i) observe all health and safety rules and regulations and any other security requirements that apply at any of CityU's premises;

(j) comply with any additional obligations as set out in the specification mentioned in the Purchase Order.

6. INTELLECTUAL PROPERTY

6.1 All Intellectual Property Rights in all drawings, designs, patterns, specifications, samples, materials, tools and other data provided by CityU in connection with the Contract, shall vest in and remain at all times the property of CityU and be used by the Supplier solely for the purpose of the Contract and all copies thereof shall be sent if requested to CityU on completion of the Contract.

6.2 The Supplier represents and warrants that it has full clear title and unrestricted rights to assign Intellectual Property Rights which it agrees to assign under the Purchase Order to CityU.

6.3 The Intellectual Property Rights in any Deliverables and all Intellectual Property Rights created in the performance of the Services, other than the Supplier Intellectual Property and any Third Party Intellectual Property, shall belong to CityU.

6.4 The Supplier grants to CityU a perpetual, irrevocable, royalty free worldwide, non-exclusive licence to use, reproduce, modify, publish, adapt, or communicate to the public and exploit the Supplier Intellectual Property in conjunction with the Goods and/or Services as part of the Deliverables.

6.5 The Supplier shall take all steps necessary to ensure CityU and their respective licensees may use the Goods and/or Deliverables and receive the Services without restrictions of any kind.

6.6 The Goods, Services and/or Deliverables supplied should not infringe upon the patent or copyright of any third party in any jurisdiction. In the case of any claim or action brought against CityU alleging infringement of any patent or copyright in respect of the Goods, Services and/or Deliverables supplied, the Supplier shall undertake to defend or settle such claim or action at its own expenses and shall indemnify all the losses and expenses of CityU including but not limited to CityU's legal expenses.

6.7 The Supplier agrees to waive and agrees not to assert any moral rights, rights of integrity, rights of paternity, or similar rights to object to or prevent modification of any the Goods and/or Deliverables, or to insist upon being identified as the creator or author of any the Goods and/or Deliverables.

7. LIABILITY FOR DAMAGES OR COMPENSATION

7.1 The Supplier shall hold and keep CityU indemnified in full against all costs, expenses, damages and losses (whether direct or indirect), including any interest, fines, legal and other professional fees and expenses awarded against or incurred or paid by CityU due to or arising out of the performance of the Contract or any breach by the Supplier of these terms and conditions or any term or obligation implied by law or any statutory provision that may be in force from time to time.

7.2 CityU shall not be liable for or in respect of any damages or compensation under the Fatal Accidents Ordinance (Chapter 22 of the Laws of Hong Kong), the Employees' Compensation Ordinance (Chapter 282 of the Laws of Hong Kong), or at common law by or in consequence of any accident or injury to any workman or other person whether in the employment of the Supplier, Contractor and/or Sub-Contractor and the Supplier shall indemnify, and keep indemnified CityU fully against any claims, demands, proceedings, costs, charges and expenses whatsoever in respect thereof or in relation thereto.

7.3 The Supplier shall effect a policy of insurance against all liability to pay damages or compensation as aforesaid in respect of all workmen and other person (other than the employees of CityU) who may be employed on any work done in pursuance of this Contract with a company approved by CityU (which approval shall not be unreasonably withheld) and shall continue such insurance during the whole of the time that any persons are employed by the Supplier on any work done in pursuance of this Contract.

7.4 If the Supplier fails to effect and keep in force the insurance referred to above or any other insurance which he may be required to effect under the terms of the Purchase Order or if the Supplier fails to show to the satisfaction of CityU that such insurance has been effected and kept with proof of payment of premium as above mentioned, then and in any such cases CityU may effect and keep in force any such insurance and pay such premium of premiums as may be necessary for that purpose and deduct or set off the amounts so paid by CityU from any moneys due or which may become due to the Supplier or recover the same as debt due from the Supplier.

7.5 In the event of any workmen or other person employed on any work done in pursuance of this Purchase Order whether in the employment of the Supplier, Contractor and/or Sub-Contractor (if appropriate) suffering any personal injury and whether there be a claim for compensation or not, the Supplier shall without delay give notice in writing of such personal injury to CityU with supporting documents (if any).

8. PAYMENT

Valid invoices for payments due in respect of the Goods, Services and/or Deliverables supplied shall be payable in accordance with the terms and detail as stated in the Purchase Order subsequent to full completion of delivery to CityU's satisfaction or, as the case may be, pursuant to acceptance as set out in clause 4 and clause 5.

9. DEPOSITS

9.1 Any sum deposited by the Supplier may be applied by CityU at its sole discretion towards satisfying the claims, loss and damage suffered by CityU owing to any default on the part of the Supplier in respect of his obligations and liabilities under this Purchase Order, and in the event of any earlier termination of the Purchase Order prior to the expiration of the contractual period the same or the balance (if any) thereof shall not be returnable to the Supplier until the date when but for such termination the Purchase Order would have expired.

9.2 The provision of clause 9.1 shall apply equally in the case of termination, without lawful excuse, of this Purchase Order by the Supplier.

9.3 The application of any deposit as aforesaid shall be without prejudice to any other right of CityU including the right to recover from the Supplier any excess not wholly absorbed by the said deposit.

10. TERMINATION

10.1 If the Supplier shall fail to deliver all or any of the Goods, Services and/or Deliverables within the time specified in the Purchase Order or as otherwise provided in clause 4 and clause 5 or if the Supplier shall be otherwise in default of the performance of his obligations under this Purchase Order, CityU shall immediately thereupon be at liberty to terminate this Contract by notice in writing addressed to the Supplier, without prejudice to CityU's right to claim against the Supplier for breaching of Contract and its loss and damage therefor, in particular, the right for CityU (i) to refuse to accept any subsequent delivery of Goods, Services and/or Deliverables which the Supplier attempts to make; (ii) to procure any outstanding Goods, Services and/or Deliverables from any other source(s) and the Supplier shall be liable for any sum or sums in excess of the prices quoted by the Supplier; and (iii) to require a refund from the Supplier of sums paid in advance for the Goods, Services and/or Deliverables that the Supplier has not delivered.

10.2 CityU may terminate the Contract and, at its option, the provision of any Goods, Services and/or Deliverables:

(a) at any time by giving the Supplier notice in writing signed by a duly authorized person for and on behalf of CityU, and in such case a fair and reasonable price shall be paid for all Goods, Services and/or Deliverables completed or expressly committed to at the time of cancellation but subject thereto. CityU shall not be liable for any loss of the Supplier, whether directly or indirectly caused by any such termination;

(b) if the Supplier is in material breach of any of its obligations under the Contract and either the breach is incapable of remedy or the Supplier has not remedied such breach within thirty (30) days of written notice requiring it to remedy that breach; or

(c) immediately on written notice if the Supplier becomes affected by an insolvency event.

10.3 Subject to clause 10.4 upon termination or expiry of the Contract, the Supplier shall forthwith return any property including confidential information of CityU which it has in its possession or control.

10.4 Without prejudice to any other right or remedy of CityU under the Contract, in the event of expiry or any termination of the Contract for any reason whatsoever, CityU may keep copies of all or any Deliverables or other products or documents delivered under the Contract.

10.5 Upon termination or expiry of the Contract the Supplier shall promptly repay CityU as a debt due all charges paid for Services which are not performed to CityU's satisfaction before the date of termination or expiry or any Purchase Price paid for Goods that have not been delivered.

11. EXTENSION OF CONTRACTUAL PERIOD

Order for Goods and/or Services placed not less than fourteen (14) days before expiration of the contractual period shall remain in force until fulfilled in accordance with the terms of this Contract notwithstanding the intervening expiration of this Contract by effluxion of time.

12. RECOVERY OF SUMS DUE

Whenever under this Contract any sum of money shall be recoverable from or payable by the Supplier, the same may be deducted from any sum then due or which at any time thereafter may become due to the Supplier under this or any contract with any department of CityU.

13. BANKRUPTCY

CityU may at any time by notice in writing summarily terminate this Contract and the Supplier shall not be entitled to compensation in any of the following events:

(a) if the Supplier shall at any time be adjudged bankrupt, or shall have a receiving order or order for administration of his estate made against him or shall take any proceedings or liquidation or compensation under any Bankruptcy Ordinance (Chapter 6 of the Laws of Hong Kong) for the time being in force, or if distress or attachment or other process of execution shall be taken or issued against the Supplier or his assets or undertakings or if he shall make any conveyance or assignment of his effects or composition or arrangement for the benefit of his creditors or if he attempts or purports so to do; or

(b) if the Supplier, being a company, shall pass a resolution for winding up or if petitions or proceedings shall be taken by any creditor of the Supplier for the winding up of the Supplier or the Court shall make an order for the liquidation of its affairs, or a Receiver or Manager on behalf of the debenture holders shall be appointed or circumstances shall arise which entitle the Court or debenture holders to appoint a Receiver or Manager;

provided always that such termination shall not prejudice or affect any right or action or remedy which shall have accrued or shall accrue thereafter to CityU.

14. PREVENTION OF BRIBERY ORDINANCE

Suppliers are warned that offering or giving any gratuity, bonus, discount, bribe, loan or any other gift or consideration as an inducement or reward to any employee of CityU in relation to this or any other CityU contract could constitute an offence contrary to the Prevention of Bribery Ordinance (Cap. 201 of the Laws of Hong Kong), and that if the Suppliers were found to have made such an offer CityU shall be at liberty to cancel the Contract and shall hold the Supplier liable for any loss or damages which CityU may thereby sustain.

15. FORCE MAJEURE

Neither party to the Contract shall be liable for any delays or failure attributable to its being affected an Event of Force Majeure, but the party so affected shall use best endeavours to resume performance as quickly as possible and shall promptly give the other party full particulars of the failure or delay and consult with the other party concerning the failure or delay from time to time as appropriate. If any such delay or failure on the part of the Supplier continues for a period of three (3) months, or for sixty (60) days in any one hundred and twenty (120) days period, CityU shall be entitled to terminate the Contract, and the provision of any Goods, Services and/or any Deliverables immediately on giving written notice to the Supplier.

16. DISPUTES AND GOVERNING LAW

The Contract and any dispute or claim arising out of or in connection with it or its subject matter or formation (including non-contractual disputes or claims) shall in all respects be governed by and construed in accordance with the laws of Hong Kong and the parties hereto irrevocably submit to the non-exclusive jurisdiction of the Hong Kong Courts in respect of the same.

17. RIGHTS OF THIRD PARTIES

Notwithstanding the Contracts (Rights of Third Parties) Ordinance (Chapter 623 of the Laws of Hong Kong), no one other than a party to this Contract will have any right to enforce any of the terms in this Contract.

18. TERMS AND CONDITIONS

These terms and conditions will apply unless CityU specifies different terms and conditions in its tender or quotation documentation or some other contract entered into by the parties. If different terms and conditions are specified by CityU those terms and conditions will override the Purchase Order terms and conditions and will apply instead of these.

20190228

CityU 香港城市大學 City University of Hong Kong

附件(3.3) 棄置育苗器的程序

Finance Office (Procurement)
General Tender Board – Tender Return Record

Buyer Name: [redacted] Department: SKLMP PR No.: T-50978/ 842766

Tender Ref. No: IT21/094AY Tender issue date: 15 October 2021 Tender closing date: 2:00 pm, 26 October 2021 (Tuesday)

Project Name: Removal and Disposal of the Fire-damaged Fish Fry Chamber at Lo Tik Wan Lamma Island

No	Name of Tenderers	Tender Sum $	No Offer	No Return
1.	[redacted]	[redacted]	–	–
2.	[redacted]		–	✓
3.	[redacted]	–	–	✓
4.	[redacted]	[redacted]	–	–
5.	[redacted]	–	–	✓
6.	[redacted]	–	–	✓
7.	[redacted]	[redacted]	–	–
8.				
9.				
10.				

Declaration

☑ I undertake to hold in strict confidence all tender information that I have access to through my position as a member of the Tender Opening Team.

☑ I undertake not to take advantage of any tender information referred to in paragraph 1 above.

☑ I hereby declare that I have no conflicts of interest in relation to this tender open in accordance with conflict of interest stated in University Policies.

Or

☐ I wish to declare conflicts of interest: *persons/companies with *whom/which I have official dealings, the relationship with the *persons/companies.

Signed by: [redacted]
Name/ Title: [redacted]
Date [redacted]

Declaration

☑ I undertake to hold in strict confidence all tender information that I have access to through my position as a member of the Tender Opening Team.

☑ I undertake not to take advantage of any tender information referred to in paragraph 1 above.

☑ I hereby declare that I have no conflicts of interest in relation to this tender open in accordance with conflict of interest stated in University Policies.

Or

☐ I wish to declare conflicts of interest: *persons/companies with *whom/which I have official dealings, the relationship with the *persons/companies.

Signed by: [redacted]
Name/ Title: [redacted]
Date [redacted]

①

Total 3pages

To: The Secretary to General Tender Board
City University of Hong Kong
Finance Office
4/F, Li Dak Sum Yip Yio Chin Academic Building
Tat Chee Avenue, Kowloon
Hong Kong
(Fax No. for submitting Tender: ***3442 0101***)

Invitation to Tender
Tender Ref.: **IT21/094AY**
(Page 1 of 2)
Date: 11 October 2021

(Tender Closing Date:
2:00 p.m., Tuesday, 26 October 2021)

Schedule & Offer

We have studied the Terms of Tender, General Conditions of Contract and the Special Conditions of Contract (if any) and do hereby agree to supply all or any portion of the articles and services mentioned in the Tender as amended by us, which may be ordered by City University of Hong Kong, at the price quoted in the Tender, for delivery on or before the date mentioned in the Tender of where placed by City University of Hong Kong free of all other charges subject to and in accordance with the Terms of Tender attached hereto.

Item	Description	Quantity	Unit Rate (DDP) HK$	Total Amount (DDP) HK$
1.	**Removal and Disposal of the Fire-damaged Fish Fry Chamber** Dimension: 21m x 7m x 5m (LxWxH) Location: Lo Tik Wan, Lamma Island **<u>Requirements</u>** (1) Contractor should provide all necessary tools, materials and labour to removal, disassemble and disposal of a fire-damaged fish fry chamber with dimension: 21m x 7m x 5m (LxWxH) located at Lo Tik Wan, Lamma Island. Please refer to photos as attached Appendix A (4 pages) for information. (2) The contractor should be responsible to provide public liability insurance coverage. (3) The contractor should be responsible to provide employees' compensation insurance coverage for those employed for the execution of the works under this contract. (4) The contractor is responsible to clear and remove all rubbish/debris incurred from Site to locations, as agreed by the CityU, at his own expenses. (5) The contractor is required to control the disposal of public fill, construction and demolition waste to designated public filling facilities and landfills respectively, all illegal dumping of waste is not accepted. (6) Allow for any other items which have not been specifically measured above but are required for the completion of the works in accordance with the requirements and statutory requirements.	1 Job		[redacted]

Tender R[redacted]
Tender Closing Date[redacted]

Schedule & Offer (Cont'd)

Item	Description	Quantity	Unit Rate (DDP) HK$	Total Amount (DDP) HK$
	Removal and Disposal of the Fire-damaged Fish Fry Chamber Dimension: 21m x 7m x 5m (LxWxH) Location: Lo Tik Wan, Lamma Island (7) All Government Fee and disposal regulation are according to Chapter 354 - Waste Disposal Ordinance. For the Fish Fry Chamber details, please refer to the attached Specification (1 Page) and Appendix A (4 Pages).			

[redacted]

[redacted]

Company Name and Chop: [redacted] Date: 25/10/2021

Schedule & Offer (Cont'd)

	The following **MUST BE** completed by Tenderer:-
a.	Time for completion of job: 14 days from placing of order.
b.	All services provided should comply with the Government Approved Regulations and Standards. (YES/~~NO~~)*
c.	Payment term: 30 days net after acceptance of goods/services and against invoice. (YES/~~NO~~)*
	*** Please delete as inappropriate**

Note to Tenderers

1. City University of Hong Kong reserves the right not to accept the lowest or any tender or any part of any tender. If a tender is submitted on the basis of overall acceptance of all the items offered, this must be clearly stated in the tender.
2. Should you require further clarifications on the Specification, please contact [redacted] of State Key Laboratory of Marine Pollution). Any other questions relating to the submission of this tender, please contac[redacted]f Finance Office at 3442 6367.
3. Please return this page by fax with signature & company chop and indicate "No Offer" on it if you are unable to supply the above product. Please also state reason of "No Offer".

☞ **If you do not receive acceptance notice from the University on or after the expiry of the tender validity, you should assume that your tender is unsuccessful.**

Remarks:	**Supplier's Reply**
Tender remains valid for acceptance within 90 days after the closing date.	We offer to supply the goods at the price stated in accordance with the specifications and conditions above.
[redacted]	Signature [redacted]
	Name
	Title
	Date
	Co. Name
	Co. Chop
	Telephone No.
for Secretary to General Tender Board	Fax No.

(4)

To: The Secretary to General Tender Board
City University of Hong Kong
Finance Office
4/F, Li Dak Sum Yip Yio Chin Academic Building
Tat Chee Avenue, Kowloon
Hong Kong
(Fax No. for submitting Tender: ***3442 0101***)

Invitation to Tender
Tender Ref.: **IT21/094AY**
(Page 1 of 2)
Date: 11 October 2021

(Tender Closing Date:
2:00 p.m., Tuesday, 26 October 2021)

Schedule & Offer

We have studied the Terms of Tender, General Conditions of Contract and the Special Conditions of Contract (if any) and do hereby agree to supply all or any portion of the articles and services mentioned in the Tender as amended by us, which may be ordered by City University of Hong Kong, at the price quoted in the Tender, for delivery on or before the date mentioned in the Tender of where placed by City University of Hong Kong free of all other charges subject to and in accordance with the Terms of Tender attached hereto.

Item	Description	Quantity	Unit Rate (DDP) HK$	Total Amount (DDP) HK$
1.	**Removal and Disposal of the Fire-damaged Fish Fry Chamber** Dimension: 21m x 7m x 5m (LxWxH) Location: Lo Tik Wan, Lamma Island **Requirements** (1) Contractor should provide all necessary tools, materials and labour to removal, disassemble and disposal of a fire-damaged fish fry chamber with dimension: 21m x 7m x 5m (LxWxH) located at Lo Tik Wan, Lamma Island. Please refer to photos as attached Appendix A (4 pages) for information. (2) The contractor should be responsible to provide public liability insurance coverage. (3) The contractor should be responsible to provide employees' compensation insurance coverage for those employed for the execution of the works under this contract. (4) The contractor is responsible to clear and remove all rubbish/debris incurred from Site to locations, as agreed by the CityU, at his own expenses. (5) The contractor is required to control the disposal of public fill, construction and demolition waste to designated public filling facilities and landfills respectively, all illegal dumping of waste is not accepted. (6) Allow for any other items which have not been specifically measured above but are required for the completion of the works in accordance with the requirements and statutory requirements.	1 Job		[redacted]

[redacted]

Tender Ref[redacted]
Tender Closing Date: [redacted]

Schedule & Offer (Cont'd)

Item	Description	Quantity	Unit Rate (DDP) HK$	Total Amount (DDP) HK$
	Removal and Disposal of the Fire-damaged Fish Fry Chamber Dimension: 21m x 7m x 5m (LxWxH) Location: Lo Tik Wan, Lamma Island (7) All Government Fee and disposal regulation are according to Chapter 354 - Waste Disposal Ordinance. For the Fish Fry Chamber details, please refer to the attached Specification (1 Page) and Appendix A (4 Pages).			

[redacted]

Company Name and [redacted] Date: Oct 25, 2021

Schedule & Offer (Cont'd)

	The following **MUST BE** completed by Tenderer:-
a.	Time for completion of job: 14 days from placing of order.
b.	All services provided should comply with the Government Approved Regulations and Standards. **(YES/~~NO~~)***
c.	Payment term: 30 days net after acceptance of goods/services and against invoice. **(YES/~~NO~~)***
	*** Please delete as inappropriate**

Note to Tenderers

1. City University of Hong Kong reserves the right not to accept the lowest or any tender or any part of any tender. If a tender is submitted on the basis of overall acceptance of all the items offered, this must be clearly stated in the tender.
2. [redacted] require further clarifications on the Specification, please contac[redacted]of State Key Laboratory of Marine Pollution). Any other questions relating to the submission of this tender, please contact [redacted]f Finance Office at 3442 6367.
3. Please return this page by fax with signature & company chop and indicate "No Offer" on it if you are unable to supply the above product. Please also state reason of "No Offer".

☞ **If you do not receive acceptance notice from the University on or after the expiry of the tender validity, you should assume that your tender is unsuccessful.**

Remarks:	**Supplier's Reply**
Tender remains valid for acceptance within 90 days after the closing date.	We offer to supply the goods at the price stated in accordance with the specifications and conditions above.
[redacted] *for* Secretary to General Tender Board	Signature Name Title Date Co. Name Co. Chop Telephone No. Fax No. [redacted]

Invitation to Tender for the Removal and Disposal of the Fire-damaged Fish Fry Chamber at Lo Tik Wan Lamma Island
(項目: 招標承投清除及移走位於北南丫島蘆荻灣海上之育苗箱構築物及其他物件服務工程)

Details of the "Fish Fry Chamber"

主力結構: 此育苗箱主力結構參照木及玻璃纖維船的構造作基礎而建造，用以抵禦海浪及各種惡劣天氣環境，結構外皮（又稱船旁)水下用樟木，出水用非洲坤甸木。

育苗箱結構及資料如下:

1. 結構由兩條底骨（即龍骨) 12 吋 x 11 吋山樟木構造而成
2. 橫柴底陣即龍骨向左右伸延的支架約三吋半厚以及橫柴高度八吋厚
3. 橫柴樓頭三吋半厚，高度為七吋厚
4. 底旁用山樟木兩吋厚，出水用坤甸木兩吋厚
5. 波橋用抄木三吋厚，前後櫃面用坤甸木
6. 擋板用坤甸木，內掃一層防蟲蛀的保護油層(又稱黑鬼油)
7. 櫃陣內坑用坤甸木三吋半厚，高為五吋厚
8. 結構外皮(船旁)間兩個橫柴收螺絲
9. 結構內榜板加有孖釘
10. 育苗相結構內玻璃纖維育苗缸的建造數量不少於 30 個，每個約長三米 x 闊 2.5 米 x 高 1 米
11. 內部裝有兩部≥20kW 發電機及育苗箱內相關防水電力裝置,溫度調節和抽氣通風系統，包括內外所有電線及插頭。
12. 不少於五條錨鏈之繫泊設施

(7)

To: The Secretary to General Tender Board
City University of Hong Kong
Finance Office
4/F, Li Dak Sum Yip Yio Chin Academic Building
Tat Chee Avenue, Kowloon
Hong Kong
(Fax No. for submitting Tender: ***3442 0101***)

Invitation to Tender
Tender Ref.: **IT21/094AY**
(Page 1 of 2)
Date: 11 October 2021

(Tender Closing Date:
2:00 p.m., Tuesday, 26 October 2021)

Schedule & Offer

We have studied the Terms of Tender, General Conditions of Contract and the Special Conditions of Contract (if any) and do hereby agree to supply all or any portion of the articles and services mentioned in the Tender as amended by us, which may be ordered by City University of Hong Kong, at the price quoted in the Tender, for delivery on or before the date mentioned in the Tender of where placed by City University of Hong Kong free of all other charges subject to and in accordance with the Terms of Tender attached hereto.

Item	Description	Quantity	Unit Rate (DDP) HK$	Total Amount (DDP) HK$
1.	**Removal and Disposal of the Fire-damaged Fish Fry Chamber** Dimension: 21m x 7m x 5m (LxWxH) Location: Lo Tik Wan, Lamma Island **Requirements** (1) Contractor should provide all necessary tools, materials and labour to removal, disassemble and disposal of a fire-damaged fish fry chamber with dimension: 21m x 7m x 5m (LxWxH) located at Lo Tik Wan, Lamma Island. Please refer to photos as attached Appendix A (4 pages) for information. (2) The contractor should be responsible to provide public liability insurance coverage. (3) The contractor should be responsible to provide employees' compensation insurance coverage for those employed for the execution of the works under this contract. (4) The contractor is responsible to clear and remove all rubbish/debris incurred from Site to locations, as agreed by the CityU. at his own expenses. (5) The contractor is required to control the disposal of public fill, construction and demolition waste to designated public filling facilities and landfills respectively, all illegal dumping of waste is not accepted. (6) Allow for any other items which have not been specifically measured above but are required for the completion of the works in accordance with the requirements and statutory requirements.	1 Job		

Tender Ref: IT21/094AY (Page 2 of 3)
[redacted] nder Closing Date: 2:00p.m., 26 October 2021

[redacted] 'd)

Item	Description [redacted]	Quantity	Unit Rate (DDP) HK$	Total Amount (DDP) HK$
	Removal and Disposal of the Fire-damaged Fish Fry Chamber Dimension: 21m x 7m x 5m (LxWxH) Location: Lo Tik Wan, Lamma Island (7) All Government Fee and disposal regulation are according to Chapter 354 - Waste Disposal Ordinance. For the Fish Fry Chamber details, please refer to the attached Specification (1 Page) and Appendix A (4 Pages).		[redacted]	[redacted]

Company Name and Chop: [redacted] Date: 25 OCTOBER 2021

Tender Ref: IT21/094AY (Page 3 of 3)
Tender Closing Date: 2:00p.m., 26 October 2021

Schedule & Offer (Cont'd)

	The following **MUST BE** completed by Tenderer:-
a.	Time for completion of job: 7 days from placing of order.
b.	All services provided should comply with the Government Approved Regulations and Standards. **(YES/~~NO~~)***
c.	Payment term: 30 days net after acceptance of goods/services and against invoice. **(YES/~~NO~~)***
	*** Please delete as inappropriate**

Note to Tenderers

1. City University of Hong Kong reserves the right not to accept the lowest or any tender or any part of any tender. If a tender is submitted on the basis of overall acceptance of all the items offered, this must be clearly stated in the tender.
2. Should you require further clarifications on the Specification, please contact [redacted] of State Key Laboratory of Marine Pollution). Any other questions relating to the submission of this tender, please contact [redacted] of Finance Office at 3442 6367.
3. Please return this page by fax with signature & company chop and indicate "No Offer" on it if you are unable to supply the above product. Please also state reason of "No Offer".

If you do not receive acceptance notice from the University on or after the expiry of the tender validity, you should assume that your tender is unsuccessful.

Remarks:	**Supplier's Reply**
Tender remains valid for acceptance within 90 days after the closing date.	We offer to supply the goods at the price stated in accordance with the specifications and conditions above.
[redacted] *for* Secretary to General Tender Board	Signature Name Title Date Co. Name Co. Chop Telephone No. Fax No. [redacted]

附件(3.4) 棄置育苗器的程序 Purchase Order 採購單

香港城市大學 City University of Hong Kong

Purchase Order No. 採購單編號 627176 Page 頁數 1 / 5

Finance Office (Procurement Unit)
4/F, Li Dak Sum Yip Yio Chin Academic Building, 83 Tat Chee Avenue, Kowloon, Hong Kong SAR
Fax: (852) 3442 0102
Website: http://www.cityu.edu.hk/fo

財務處(採購組)
香港九龍達之路83號
李達三葉耀珍學術樓四樓
電傳: (852) 3442 0102
網址: http://www.cityu.edu.hk/fo

P.O. Issue Date 採購單日期 08-NOV-2021

Revision No. 更正版本編號 1 Revised Date 更正版本日期 08-NOV-2021

THIS ORDER NUMBER MUST BE QUOTED ON ALL CORRESPONDENCE CONCERNING THIS ORDER
請在所有文件上註明採購單編號

[redacted]

Ship to: 送貨地點
STATE KEY LABORATORY OF MARINE POLLUTION
RM P5840 (LIFT 17), YEUNG KIN MAN ACADEMIC BLDG
TAT CHEE AVENUE
KOWLOON, HONG KONG SAR

ATTN: [redacted]
TEL: [redacted]
FAX:
EMAIL: [redacted]

Bill to: 發票寄往
To avoid late payment, original invoice MUST BE sent to:
FINANCE OFFICE - TREASURY UNIT, 4/F., LI DAK SUM YIP YIO CHIN ACADEMIC BLDG., TAT CHEE AVENUE, KOWLOON (T: 34426323 / F: 34420102), HONG KONG SAR

Vendor No.	供應商編號	71045704	Requester	申請人	[redacted]
Payment Terms	付款條件	30 Days Net	Tel. No.	電話號碼	(852)34429438
Ship Via	付運方法		Buyer	採購員	[redacted]
Freight Terms	付運條款		Tel. No.	電話號碼	(852)34426367
Tender ref.	投標編號		Document ref.	文件編號	

ITEM 項目	DESCRIPTION 內容	QUANTITY 數量	UNIT PRICE 單價	AMOUNT 總額
	Note to Supplier:-			

Tender Ref.: IT21/094AY
Your returned tender dated 25 Oct 2021 refers.

For job details, please contact [redacted].

- This is a computer produced Purchase Order and requires no signature
- For terms & conditions of the purchases, please refer to our General Conditions of Contract attached

Total 採購單總額 CIF H.K. Campus

Continued...

香港城市大學
City University of Hong Kong

Finance Office (Procurement Unit)
4/F, Li Dak Sum Yip Yio Chin Academic Building, 83 Tat Chee Avenue,
Kowloon, Hong Kong SAR
Fax: (852) 3442 0102
Website: http://www.cityu.edu.hk/fo

財務處(採購組)
香港九龍達之路83號
李達三葉耀珍學術樓四樓
電傳: (852) 3442 0102
網址: http://www.cityu.edu.hk/fo

Purchase Order 採購單

Purchase Order No. 採購單編號 627176

P.O. Issue Date 採購單日期 08-NOV-2021

Revision No. 更正版本編號 1 Revised Date 更正版本日期 08-NOV-2021

THIS ORDER NUMBER MUST BE QUOTED ON ALL CORRESPONDENCE CONCERNING THIS ORDER
請在所有文件上註明採購單編號

[redacted]

ATTN: [redacted]
TEL: [redacted]
FAX:
EMAIL: [redacted]

Ship to: 送貨地點
STATE KEY LABORATORY OF MARINE POLLUTION
RM P5840 (LIFT 17), YEUNG KIN MAN ACADEMIC BLDG
TAT CHEE AVENUE
KOWLOON, HONG KONG SAR

Bill to: 發票寄往
To avoid late payment, original invoice MUST BE sent to:
FINANCE OFFICE - TREASURY UNIT, 4/F., LI DAK SUM YIP YIO CHIN ACADEMIC BLDG., TAT CHEE AVENUE, KOWLOON (T: 34426323 / F: 34420102), HONG KONG SAR

Vendor No.	供應商編號	[redacted]	Requester	申請人	[redacted]
Payment Terms	付款條件	30 Days Net	Tel. No.	電話號碼	(852)34429438
Ship Via	付運方法		Buyer	採購員	[redacted]
Freight Terms	付運條款		Tel. No.	電話號碼	(852)34426367
Tender ref.	投標編號		Document ref.	文件編號	

ITEM 項目	DESCRIPTION 內容	QUANTITY 數量	UNIT PRICE 單價	AMOUNT 總額
1.	Removal and Disposal of the Fire-damaged Fish Fry Chamber, Dimension: 21m x7m x5m (LxWxH) Location: Lo Tik Wan, Lamma Island			[redacted]

Requirements:

(1) Contractor should provide all necessary tools, materials and labour to removal, disassemble and disposal of a fire-damaged fish fry chamber with dimension: 21m x 7m x 5m (LxWxH) located at Lo Tik Wan, Lamma Island. Please refer to photos as attached Appendix A (4 pages) for information.

(2) The contractor should be responsible to provide public liability insurance coverage.

(3) The contractor should be responsible to provide employees ’ compensation insurance coverage for those employed for the execution of the works under this contract.

(4) The contractor is responsible to clear and remove all rubbish/debris incurred from Site to locations, as agreed by the CityU, at his own expenses.

(5) The contractor is required to control the disposal of public fill, construction and demolition waste to designated public filling facilities and landfills respectively, all illegal dumping of waste is not accepted.

(6) Allow for any other items which have not been specifically measured above but are required for the completion of the works in accordance with the requirements and statutory requirements.

- This is a computer produced Purchase Order and requires no signature
- For terms & conditions of the purchases, please refer to our General Conditions of Contract attached

Total 採購單總額
CIF H.K. Campus

Continued...

Purchase Order 採購單

Finance Office (Procurement Unit)
4/F, Li Dak Sum Yip Yio Chin Academic Building, 83 Tat Chee Avenue,
Kowloon, Hong Kong SAR
Fax: (852) 3442 0102
Website: http://www.cityu.edu.hk/fo

財務處(採購組)
香港九龍達之路83號
李達三葉耀珍學術樓四樓
電傳: (852) 3442 0102
網址: http://www.cityu.edu.hk/fo

Purchase Order No. 採購單編號 627176

P.O. Issue Date 採購單日期 08-NOV-2021

Revision No. 更正版本編號 1 Revised Date 更正版本日期 08-NOV-2021

THIS ORDER NUMBER MUST BE QUOTED ON ALL CORRESPONDENCE CONCERNING THIS ORDER
請在所有文件上註明採購單編號

[redacted]
HONG KONG SAR

ATTN: [redacted]
TEL: [redacted]
FAX:
EMAIL: [redacted]

Ship to: 送貨地點
STATE KEY LABORATORY OF MARINE POLLUTION
RM P5840 (LIFT 17), YEUNG KIN MAN ACADEMIC BLDG
TAT CHEE AVENUE
KOWLOON, HONG KONG SAR

Bill to: 發票寄往
To avoid late payment, original invoice MUST BE sent to:
FINANCE OFFICE - TREASURY UNIT, 4/F., LI DAK SUM YIP YIO CHIN ACADEMIC BLDG., TAT CHEE AVENUE, KOWLOON (T: 34426323 / F: 34420102), HONG KONG SAR

Vendor No.	供應商編號	[redacted]	Requester	申請人	[redacted]
Payment Terms	付款條件	30 Days Net	Tel. No.	電話號碼	(852)34429438
Ship Via	付運方法		Buyer	採購員	[redacted]
Freight Terms	付運條款		Tel. No.	電話號碼	(852)34426367
Tender ref.	投標編號		Document ref.	文件編號	

ITEM 項目	DESCRIPTION 內容	QUANTITY 數量	UNIT PRICE 單價	AMOUNT 總額
	(7) All Government Fee and disposal regulation are according to Chapter 354 - Waste Disposal Ordinance.			

DELIVERY DATE (送貨日期): ON OR BEFORE 30-DEC-2021
PR#:842766-1 A/C: 620.000.3115.000.1 (PJ# 9605001) CAT. CODE:S87120

- This is a computer produced Purchase Order and requires no signature
- For terms & conditions of the purchases, please refer to our General Conditions of Contract attached

Total 採購單總額 HKD [redacted]
CIF H.K. Campus

香港城市大學
City University of Hong Kong
Finance Office (Procurement Unit)

GENERAL TERMS AND CONDITIONS FOR GOODS AND/OR SERVICES

1. DEFINITIONS

Unless the context otherwise requires, the following terms have the following meanings:

(a) **"CityU"** means City University of Hong Kong;

(b) **"Contract"** means the contract between CityU and the Supplier for the supply of Goods and/or Services comprising the Purchase Order and the terms and conditions;

(c) **"Deliverables"** means any document or product that is to be delivered to CityU by the Supplier in the course of providing the Services, including (without limitation) any such product or document that is described as such in the Purchase Order;

(d) **"Delivery Location"** means the location(s) for the supply of the Goods and/or Services set out in the Purchase Order;

(e) **"Goods"** means the goods to be provided as described in the Purchase Order;

(f) **"Intellectual Property Rights"** means all present and future rights conferred by statute, common law or equity in any territory in or in relation to copyright and related rights, moral rights, trademarks, designs rig, patents, circuit layouts, business and domain names and all applications (and rights to apply) therefor;

(g) **"Purchase Order"** means the purchase order to which these terms and conditions are attached;

(h) **"Premises"** means any premises occupied by CityU;

(i) **"Purchase Price"** means the prices for the Goods and/or the charges for the Services set out in the Purchase Order;

(j) **"Services"** means the services to be provided as described in the Purchase Order;

(k) **"Supplier"** means the person or firm specified in the Purchase Order from whom CityU purchases the Good and/or Services;

(l) **"Supplier Personnel"** means all employees, agents, suppliers, contractors, and subcontractors of the Supplier who are involved in the provision of Services or the supply of Goods;

(m) **"Warranty Period"** means a period of twelve months after the acceptance of the Goods, Services and/or Deliverables or such other period as specified in the Purchase Order.

2. GENERAL

2.1 The Purchase Order constitutes an acceptance by CityU of the quotation or offer provided by the Supplier. The acknowledgement or execution of the Purchase Order or by performance of the Services or supply of the Goods set out therein shall mean Supplier's acceptance of all the terms and conditions of the Contract.

2.2 The Purchase Order once accepted, combined with these terms and conditions and/or any attachment expressly incorporated in writing shall be deemed to bind the Supplier to the Contract.

2.3 No variation, waiver, modification, deletion or addition to the terms and conditions of the Purchase Order shall be binding upon the parties unless approved in writing by CityU and attached to this Purchase Order.

2.4 The Purchase Order is not exclusive and CityU shall not be restricted from purchasing services similar to and/or identical to the Services or goods similar to the Goods from any third parties.

2.5 The Supplier shall not assign, transfer, subcontract or deal in any other manner with all or any of its right or obligations under the Purchase Order without the prior written consent of CityU.

3. SUPPLIER'S WARRANTIES

The Supplier represents and warrants:

(a) it has full clear title, rights, licences, interests and property necessary to provide the Goods, Deliverables and/or perform the Services;

(b) it shall comply (and shall procure that all Supplier Personnel shall comply) with all applicable laws in relation to the provision of the Goods, Services and/or Deliverables;

(c) it shall ensure that any Goods, Services and/or Deliverables shall be:

i. of the specific quality indicated in the Purchase Order;

ii. of merchantable and satisfactory quality;

iii. fit for any purpose held out by the Supplier or made known to the Supplier or intended by CityU;

iv. in conformance with any samples provided to CityU;

(d) the Goods, Services and/or Deliverables are to be guaranteed against faulty workmanship and faulty materials and remain so for the Warranty Period. All repairs and replacements within the Warranty Period shall be carried out free of charge by the Supplier;

(e) it shall not make any payment or offer anything of value, or request, or accept a financial or other advantage either directly or indirectly, where such payment, offer, or request could be or may be considered to have the purpose or effect of public or commercial bribery or to constitute the acceptance of, corruption, extortion, kickbacks, or other unlawful means of obtaining business.

4. **DELIVERY, INSPECTION AND ACCEPTANCE OF GOODS AND DELIVERABLES**

4.1 The Purchase Price set out in the Purchase Order includes packaging and delivery. The Supplier shall be responsible for and shall bear the cost of unloading all Goods and/or Deliverables to the Delivery Location or Delivery Locations as instructed by CityU from time to time.

4.2 The Supplier shall use suitable packaging and delivery method to ensure the Goods and/or Deliverables are delivered in good condition without damage; Time is of the essence with respect to the Supplier's delivery obligations under the Contract, or if no such time period is specified, the Supplier shall deliver the Goods and/or Deliverables on the date of the specified in the Purchase Order.

4.3 Each delivery of the Goods and/or Deliverables is accompanied by a delivery note which shows the date of the Purchase Order, the Purchase Order number, the type and quantity of the Goods and/or Deliverables including the code number of the Goods and/or Deliverables (where applicable), special storage instructions (if any) and, if the Goods and/or Deliverables are being delivered by instalments, the outstanding balance of Goods and/or Deliverables to be delivered.

4.4 (a) All deliveries of the Goods and/or Deliverables are subject to inspection and test by CityU and accordingly shall not be regarded as accepted. If the Goods and/or Deliverables are found not in accordance with any of the details shown in the Purchase Order, CityU reserves the right to reject and return the Goods and/or Deliverables to the Supplier at Supplier's expense;

(b) within twenty-four (24) hours of being notified in writing of the rejection of any goods delivered the Supplier shall remove the same;

(c) within seven (7) days of notification of rejection, the Supplier shall replace such goods with satisfactory goods specified in the Purchase Order or in the case where replacement goods have to be obtained from such sources outside Hong Kong, the Supplier must advise CityU the delivery date when replacement goods will be delivered unless with the notification of rejection, CityU shall have notified the Supplier that he does not require the replacement of such goods. CityU reserves the right to apply clause 10 in the event that replacement delivery cannot be made within the seven (7) days period referred to above whether or not replacement goods have to be obtained from sources outside Hong Kong or otherwise;

(d) the decision of CityU of rejection shall be final;

(e) if it shall prove to the satisfaction of CityU that the Supplier has offered for delivery any goods which have previously been rejected by CityU, CityU shall thereupon be at liberty to terminate this Contract in clause 10 of this Contract.

4.5 If the Goods and/or Deliverables are delivered in excess of the quantities ordered, CityU shall not be bound to pay for the excess and any excess shall be and shall remain at the Supplier's risk and shall be returned at the Supplier's expense.

4.6 The Supplier shall not deliver the Goods and/or Deliverables in instalments without CityU's prior written consent. Where it is agreed that the Goods and/or Deliverables are delivered by instalments, they may be invoiced and paid for separately.

4.7 Title and risk of the Goods and/or Deliverables delivered by the Supplier to the Premises in connection with the Purchase Order shall pass to CityU on satisfactory completion of delivery.

4.8 CityU shall be entitled at any time to defer the date of delivery of the Goods and/or Deliverables or the date for performance of the Services. Any such deferment shall not give rise to any legal right of action of any kind whatsoever on the part of the Supplier.

4.9 Without prejudice to any other provisions in the Contract, the Supplier agrees that it shall be responsible for making good with all possible speed at its own expenses any defect in or damage to any portion of the Goods and/or Deliverables which may develop during the Warranty Period, for that portion which results in a failure of the Goods and/or Deliverables to fulfil the specification or function or to meet the level of performance detailed in the Contract or arises from either defective materials, including software, workmanship or design or any act or omission of the Supplier during the Warranty Period.

4.10 If the Supplier in his tender has requested the return of empties to him he shall be entitled unless otherwise provided for under the Contract, to collect the same at any time after the expiration of twenty-eight (28) days from the date of delivery (or such earlier date as may be arranged with CityU) at his own cost and CityU shall not be liable in any way in respect of the loss of damage or such empties whilst under their control.

4.11 Any drawings and specifications reasonably required for the Supplier's guidance in the execution of this Contract shall be furnished free of charge but shall be returned on completion of the Contract. Supplier shall hold all materials, equipment and tools, drawings, specifications and data supplied by CityU to the Supplier ("Customer Materials") in safe custody at his own risk, maintain the Customer Materials in good condition until returned to CityU, and not dispose or use the Customer Materials other than in accordance with CityU's written instructions or authorization.

4.12 If required the Supplier shall furnish CityU with a proof note or certificate showing that the Goods and/or Deliverables have been subjected to the normal tests for such Goods or such tests as CityU may reasonably require.

5. DELIVERY AND ACCEPTANCE OF SERVICES

In the performance of the Services the Supplier warrants to CityU that the Supplier shall:

(a) complete the Services to the satisfaction of CityU within the period or on the date(s) specified in the Purchase Order and time is of the essence with respect to the Supplier's delivery obligations under the Contract;

(b) co-operate with CityU in all matters relating to the Services, and comply with all reasonable instructions and relevant policies and procedures of CityU;

(c) use Supplier Personnel who are suitably skilled, experienced and qualified for the roles; and in sufficient number to ensure that the Supplier's obligation are fulfilled in accordance with the Contract;

(d) ensure that the Services shall conform with all descriptions and specifications set out in the specification of the Service, and that the Deliverables shall be fit for any purpose expressly or impliedly made known to the Supplier by CityU;

(e) use the best quality goods, materials, standards and techniques, and ensure that the Deliverables, and all goods and materials supplied and used in the Services shall be free from defects in workmanship, installation and design;

(f) ensure that the Services are performed with due diligence, reasonable skill and care and in accordance with best industry practice at all times;

(g) when performing Services at any Premises, the Supplier shall minimise disruption to the normal operations of CityU and comply with the instructions given by CityU's representatives at the Premises;

(h) provide all equipment, tools and vehicles and such other items which are required to provide the Services;

(i) observe all health and safety rules and regulations and any other security requirements that apply at any of CityU's premises;

(j) comply with any additional obligations as set out in the specification mentioned in the Purchase Order.

6. INTELLECTUAL PROPERTY

6.1 All Intellectual Property Rights in all drawings, designs, patterns, specifications, samples, materials, tools and other data provided by CityU in connection with the Contract, shall vest in and remain at all times the property of CityU and be used by the Supplier solely for the purpose of the Contract and all copies thereof shall be sent if requested to CityU on completion of the Contract.

6.2 The Supplier represents and warrants that it has full clear title and unrestricted rights to assign Intellectual Property Rights which it agrees to assign under the Purchase Order to CityU.

6.3 The Intellectual Property Rights in any Deliverables and all Intellectual Property Rights created in the performance of the Services, other than the Supplier Intellectual Property and any Third Party Intellectual Property, shall belong to CityU.

6.4 The Supplier grants to CityU a perpetual, irrevocable, royalty free worldwide, non-exclusive licence to use, reproduce, modify, publish, adapt, or communicate to the public and exploit the Supplier Intellectual Property in conjunction with the Goods and/or Services as part of the Deliverables.

6.5 The Supplier shall take all steps necessary to ensure CityU and their respective licensees may use the Goods and/or Deliverables and receive the Services without restrictions of any kind.

6.6 The Goods, Services and/or Deliverables supplied should not infringe upon the patent or copyright of any third party in any jurisdiction. In the case of any claim or action brought against CityU alleging infringement of any patent or copyright in respect of the Goods, Services and/or Deliverables supplied, the Supplier shall undertake to defend or settle such claim or action at its own expenses and shall indemnify all the losses and expenses of CityU including but not limited to CityU's legal expenses.

6.7 The Supplier agrees to waive and agrees not to assert any moral rights, rights of integrity, rights of paternity, or similar rights to object to or prevent modification of any the Goods and/or Deliverables, or to insist upon being identified as the creator or author of any the Goods and/or Deliverables.

7. LIABILITY FOR DAMAGES OR COMPENSATION

7.1 The Supplier shall hold and keep CityU indemnified in full against all costs, expenses, damages and losses (whether direct or indirect), including any interest, fines, legal and other professional fees and expenses awarded against or incurred or paid by CityU due to or arising out of the performance of the Contract or any breach by the Supplier of these terms and conditions or any term or obligation implied by law or any statutory provision that may be in force from time to time.

7.2 CityU shall not be liable for or in respect of any damages or compensation under the Fatal Accidents Ordinance (Chapter 22 of the Laws of Hong Kong), the Employees' Compensation Ordinance (Chapter 282 of the Laws of Hong Kong), or at common law by or in consequence of any accident or injury to any workman or other person whether in the employment of the Supplier, Contractor and/or Sub-Contractor and the Supplier shall indemnify, and keep indemnified CityU fully against any claims, demands, proceedings, costs, charges and expenses whatsoever in respect thereof or in relation thereto.

7.3 The Supplier shall effect a policy of insurance against all liability to pay damages or compensation as aforesaid in respect of all workmen and other person (other than the employees of CityU) who may be employed on any work done in pursuance of this Contract with a company approved by CityU (which approval shall not be unreasonably withheld) and shall continue such insurance during the whole of the time that any persons are employed by the Supplier on any work done in pursuance of this Contract.

7.4 If the Supplier fails to effect and keep in force the insurance referred to above or any other insurance which he may be required to effect under the terms of the Purchase Order or if the Supplier fails to show to the satisfaction of CityU that such insurance has been effected and kept with proof of payment of premium as above mentioned, then and in any such cases CityU may effect and keep in force any such insurance and pay such premium of premiums as may be necessary for that purpose and deduct or set off the amounts so paid by CityU from any moneys due or which may become due to the Supplier or recover the same as debt due from the Supplier.

7.5 In the event of any workmen or other person employed on any work done in pursuance of this Purchase Order whether in the employment of the Supplier, Contractor and/or Sub-Contractor (if appropriate) suffering any personal injury and whether there be a claim for compensation or not, the Supplier shall without delay give notice in writing of such personal injury to CityU with supporting documents (if any).

8. PAYMENT

Valid invoices for payments due in respect of the Goods, Services and/or Deliverables supplied shall be payable in accordance with the terms and detail as stated in the Purchase Order subsequent to full completion of delivery to CityU's satisfaction or, as the case may be, pursuant to acceptance as set out in clause 4 and clause 5.

9. DEPOSITS

9.1 Any sum deposited by the Supplier may be applied by CityU at its sole discretion towards satisfying the claims, loss and damage suffered by CityU owing to any default on the part of the Supplier in respect of his obligations and liabilities under this Purchase Order, and in the event of any earlier termination of the Purchase Order prior to the expiration of the contractual period the same or the balance (if any) thereof shall not be returnable to the Supplier until the date when but for such termination the Purchase Order would have expired.

9.2 The provision of clause 9.1 shall apply equally in the case of termination, without lawful excuse, of this Purchase Order by the Supplier.

9.3 The application of any deposit as aforesaid shall be without prejudice to any other right of CityU including the right to recover from the Supplier any excess not wholly absorbed by the said deposit.

10. TERMINATION

10.1 If the Supplier shall fail to deliver all or any of the Goods, Services and/or Deliverables within the time specified in the Purchase Order or as otherwise provided in clause 4 and clause 5 or if the Supplier shall be otherwise in default of the performance of his obligations under this Purchase Order, CityU shall immediately thereupon be at liberty to terminate this Contract by notice in writing addressed to the Supplier, without prejudice to CityU's right to claim against the Supplier for breaching of Contract and its loss and damage therefor, in particular, the right for CityU (i) to refuse to accept any subsequent delivery of Goods, Services and/or Deliverables which the Supplier attempts to make; (ii) to procure any outstanding Goods, Services and/or Deliverables from any other source(s) and the Supplier shall be liable for any sum or sums in excess of the prices quoted by the Supplier; and (iii) to require a refund from the Supplier of sums paid in advance for the Goods, Services and/or Deliverables that the Supplier has not delivered.

10.2 CityU may terminate the Contract and, at its option, the provision of any Goods, Services and/or Deliverables:

(a) at any time by giving the Supplier notice in writing signed by a duly authorized person for and on behalf of CityU, and in such case a fair and reasonable price shall be paid for all Goods, Services and/or Deliverables completed or expressly committed to at the time of cancellation but subject thereto. CityU shall not be liable for any loss of the Supplier, whether directly or indirectly caused by any such termination;

(b) if the Supplier is in material breach of any of its obligations under the Contract and either the breach is incapable of remedy or the Supplier has not remedied such breach within thirty (30) days of written notice requiring it to remedy that breach; or

(c) immediately on written notice if the Supplier becomes affected by an insolvency event.

10.3 Subject to clause 10.4 upon termination or expiry of the Contract, the Supplier shall forthwith return any property including confidential information of CityU which it has in its possession or control.

10.4 Without prejudice to any other right or remedy of CityU under the Contract, in the event of expiry or any termination of the Contract for any reason whatsoever, CityU may keep copies of all or any Deliverables or other products or documents delivered under the Contract.

10.5 Upon termination or expiry of the Contract the Supplier shall promptly repay CityU as a debt due all charges paid for Services which are not performed to CityU's satisfaction before the date of termination or expiry or any Purchase Price paid for Goods that have not been delivered.

11. EXTENSION OF CONTRACTUAL PERIOD

Order for Goods and/or Services placed not less than fourteen (14) days before expiration of the contractual period shall remain in force until fulfilled in accordance with the terms of this Contract notwithstanding the intervening expiration of this Contract by effluxion of time.

12. RECOVERY OF SUMS DUE

Whenever under this Contract any sum of money shall be recoverable from or payable by the Supplier, the same may be deducted from any sum then due or which at any time thereafter may become due to the Supplier under this or any contract with any department of CityU.

13. BANKRUPTCY

CityU may at any time by notice in writing summarily terminate this Contract and the Supplier shall not be entitled to compensation in any of the following events:

(a) if the Supplier shall at any time be adjudged bankrupt, or shall have a receiving order or order for administration of his estate made against him or shall take any proceedings or liquidation or compensation under any Bankruptcy Ordinance (Chapter 6 of the Laws of Hong Kong) for the time being in force, or if distress or attachment or other process of execution shall be taken or issued against the Supplier or his assets or undertakings or if he shall make any conveyance or assignment of his effects or composition or arrangement for the benefit of his creditors or if he attempts or purports so to do; or

(b) if the Supplier, being a company, shall pass a resolution for winding up or if petitions or proceedings shall be taken by any creditor of the Supplier for the winding up of the Supplier or the Court shall make an order for the liquidation of its affairs, or a Receiver or Manager on behalf of the debenture holders shall be appointed or circumstances shall arise which entitle the Court or debenture holders to appoint a Receiver or Manager;

provided always that such termination shall not prejudice or affect any right or action or remedy which shall have accrued or shall accrue thereafter to CityU.

14. PREVENTION OF BRIBERY ORDINANCE

Suppliers are warned that offering or giving any gratuity, bonus, discount, bribe, loan or any other gift or consideration as an inducement or reward to any employee of CityU in relation to this or any other CityU contract could constitute an offence contrary to the Prevention of Bribery Ordinance (Cap. 201 of the Laws of Hong Kong), and that if the Suppliers were found to have made such an offer CityU shall be at liberty to cancel the Contract and shall hold the Supplier liable for any loss or damages which CityU may thereby sustain.

15. FORCE MAJEURE

Neither party to the Contract shall be liable for any delays or failure attributable to its being affected an Event of Force Majeure, but the party so affected shall use best endeavours to resume performance as quickly as possible and shall promptly give the other party full particulars of the failure or delay and consult with the other party concerning the failure or delay from time to time as appropriate. If any such delay or failure on the part of the Supplier continues for a period of three (3) months, or for sixty (60) days in any one hundred and twenty (120) days period, CityU shall be entitled to terminate the Contract, and the provision of any Goods, Services and/or any Deliverables immediately on giving written notice to the Supplier.

16. DISPUTES AND GOVERNING LAW

The Contract and any dispute or claim arising out of or in connection with it or its subject matter or formation (including non-contractual disputes or claims) shall in all respects be governed by and construed in accordance with the laws of Hong Kong and the parties hereto irrevocably submit to the non-exclusive jurisdiction of the Hong Kong Courts in respect of the same.

17. RIGHTS OF THIRD PARTIES

Notwithstanding the Contracts (Rights of Third Parties) Ordinance (Chapter 623 of the Laws of Hong Kong), no one other than a party to this Contract will have any right to enforce any of the terms in this Contract.

18. TERMS AND CONDITIONS

These terms and conditions will apply unless CityU specifies different terms and conditions in its tender or quotation documentation or some other contract entered into by the parties. If different terms and conditions are specified by CityU those terms and conditions will override the Purchase Order terms and conditions and will apply instead of these.

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附件(3.5) 棄置育苗器的程序

圖 1 : 2022 年 1 月 7 日，承判商用拖船移走育苗器。

圖 2 : 2022 年 1 月，育苗器運到醉酒灣，進行拆卸工程。

育苗器設備及日常操作手冊

漁業持續發展基金項目 SFDF-0016
魚排上建立示範及教育單位展示商業上可行的循環海水育苗系統

附件(4) 育苗器設備及日常操作手冊

香港城市大學
City University of Hong Kong
SKLMP 海洋污染國家重點實驗室
香港優質水產養殖業發展協會

主辦機構:
香港城市大學 海洋污染國家重點實驗室

電話 : + (852) 3442-6504
電郵 : sklmp.info@cityu.edu.hk
地址 : 香港九龍達之路香港城市大學楊建文學術樓P5840室

協辦機構:
香港優質水產養殖業發展協會

資助機構:
漁農自然護理署 漁業持續發展基金

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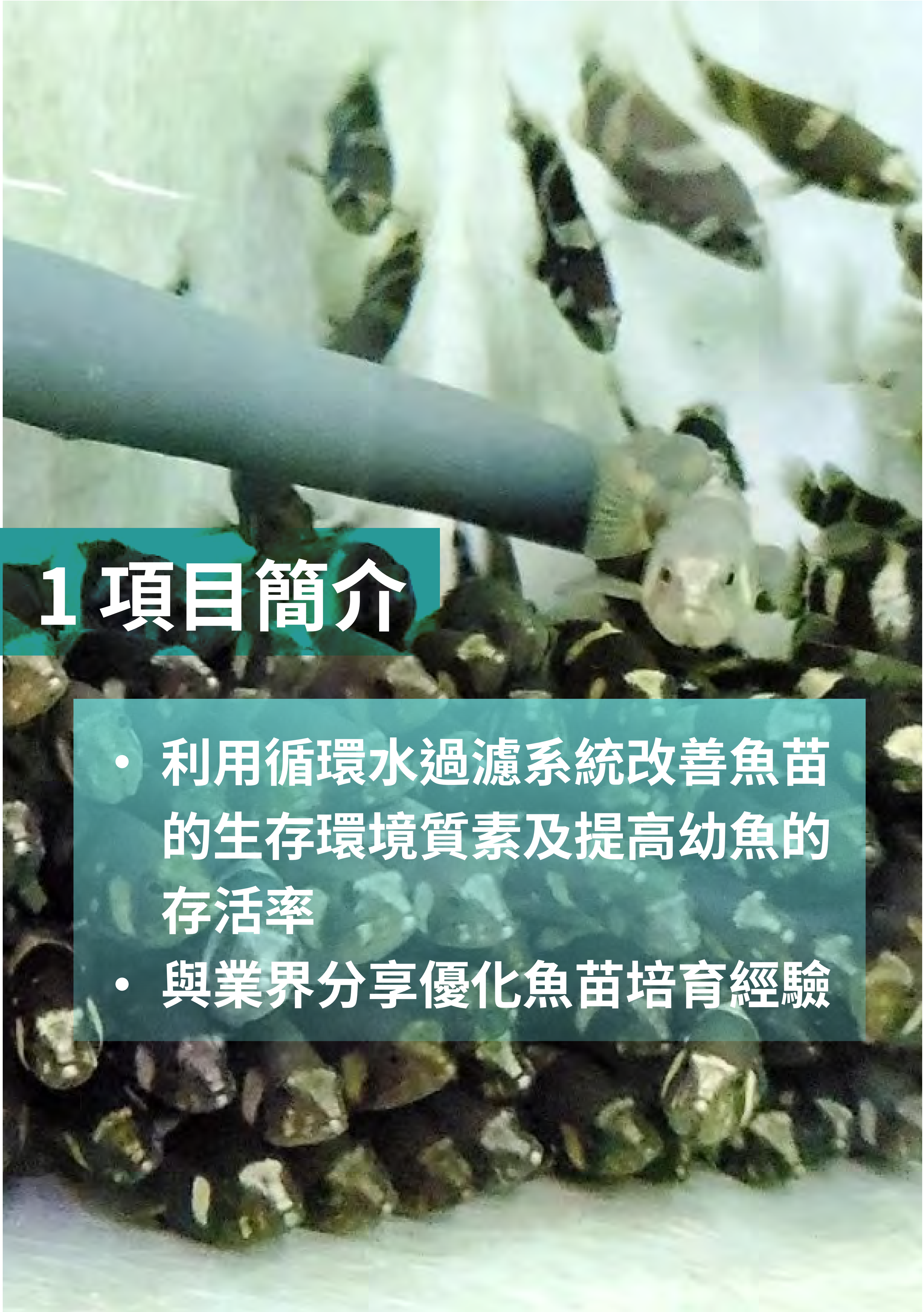


1 項目簡介

- 利用循環水過濾系統改善魚苗的生存環境質素及提高幼魚的存活率
- 與業界分享優化魚苗培育經驗

香港城市大學海洋污染國家重點實驗室 (SKLMP) 聯合香港本地水產養殖專家及獸醫，共同研發適合本地環境的水產養殖科技，同時配合本土養殖業的豐富經驗，藉以協助業界解決目前本港養殖業最大難題之一：提高魚苗和幼魚的存活率。

1.1 優質魚苗的重要性

根據本港養殖業經驗，魚苗質素和存活率是整個養殖周期中最主要的成功關鍵因素之一。目前香港的魚苗主要從外地進口，例如中國大陸、印尼、馬來西亞及台灣等地。養殖戶進口魚苗時，若選擇早期較小的魚苗，價錢及運輸成本相對較低，而且投放密度較高，但是卻面臨存活率低的極大投資風險，而養殖戶若選擇晚期較大的魚苗，魚群抗病力高，耐寒且養殖時間短，可儘快獲利，但是最大的困難是價錢及運輸成本相對提高且運輸量低，增加了整體養殖成本。為了要解決這兩難的情況，其中一種方法是將進口的早期較小魚苗，先以密閉式循環水過濾系統將魚苗小心地培育成較大的幼魚，才進行開放式海水網箱放養。這方法可以有效阻隔紅潮及寄生蟲的侵害，大大提高幼魚的存活率。

上述方式看似簡單，但其技術、設備與操作知識卻相對有較高要求，然而由於普遍養殖戶不僅缺乏相關的技術訓練與標準養殖操作指引，更無法得知其長期商業成效，所以業界極需一套有系統的養殖示範及專業培訓，了解新式養殖方法的可靠性並確保認識投資的風險與回報，藉此提升本港養殖業技術。

項目簡介

循環水過濾系統的特點

優點

- 良好水質：有水質監控，較穩定；
- 容易監察魚苗狀態/食慾，有異常情況可以立即應對，如隔離治病，減低大量感染風險；
- 有效阻隔細菌/寄生蟲/紅潮傷害；
- 減少染病，減少使用藥物(如抗生素)，容易監察餵飼量，減少/回收有機廢物，有助改善養魚區自然生態環境，持續發展；
- 增加魚苗/幼魚存活率。

缺點

- 需經常反覆檢查水質、設備、魚苗情況；
- 多部件，多項維修保養，需時間金錢人力；
- 需有穩定供電設施；
- 用電需求高，電費比較高。

1.2 優化魚苗育成方案

1.2.1 示範魚種及來源

石斑魚是亞太地區最具經濟價值的養殖魚種。石斑魚由於成長快速、廣鹽性、適應本地養殖水溫，且易於管理加上市場售價高，所以一直深受香港養殖戶垂青。目前香港多由中國大陸、東南亞及台灣等地進口石斑魚魚苗，常見品種為青斑、芝麻斑、花尾龍躉與沙巴龍躉等。 本項目亦選擇本地漁民所熟悉的魚苗來源，這樣不但不會增加漁民的經濟壓力以及養殖技術難度，同時亦有利於明確地比較出不同養殖方式的成效。

1.2.2 中間育成方案

魚苗是養殖過程中死亡率最高的階段，魚苗的育成是石斑魚養殖技術的關鍵。本項目以優質石斑魚種(例如: 花尾龍躉)魚苗開展中間育成，包括發展系統化的設備，紀錄及歸納工作程序，目標是從約 2.5 吋魚苗(~6cm) 經優化中間育成至約5吋幼魚(~12cm)。短期不僅可為附近養殖戶提供養殖風險小，利潤高的大魚苗或幼魚，長期也可推廣養殖戶自己進行魚苗的中間育成並提升行業的可持續發展。

1.2.3 向業界示範及推廣

本港現有26 個養魚區，面積約209 公頃持牌的海魚養殖者 925 名，部份養殖戶以 獨資、合作或合資的形式在沿海港灣飼養優質海水商品魚，其中又以石斑魚為優勢養殖物種，故此，優質而穩定的石斑幼魚需求甚殷，亦有助降低養殖業的起步風險，本項目最終目的是與業界分享本項目的優化魚苗培育經驗。

2 項目選址

南丫島蘆荻灣養魚區

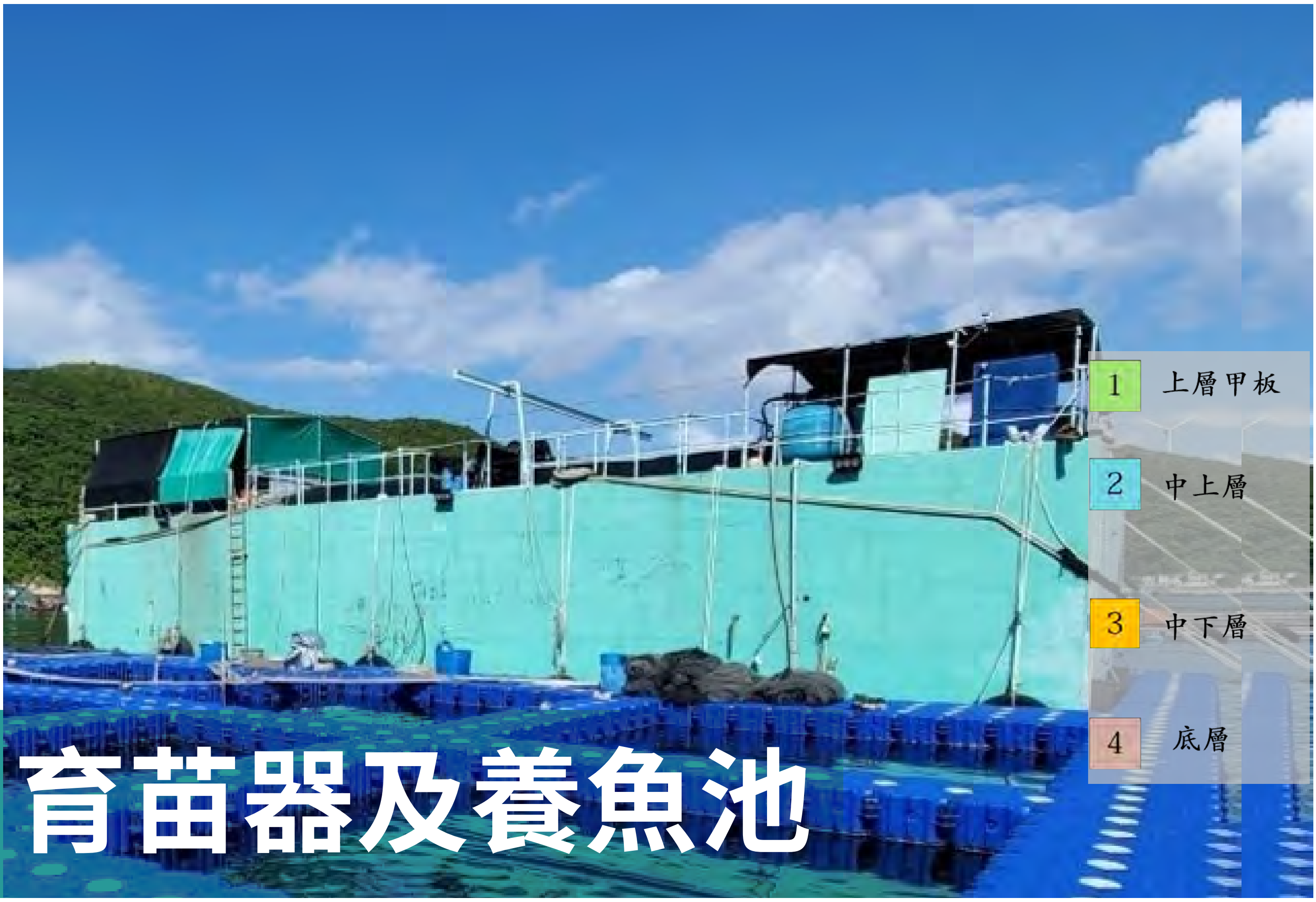
南丫島蘆荻灣養魚區具有良好水環境、交通便利、充足水電供應配套的優勢，同時當地漁民也具有豐富養殖經驗，本項目的協辦機構香港優質水產養殖業發展協會主席梁冠華先生也是當區的養殖戶，故項目於該養殖區設置魚苗育成設備。

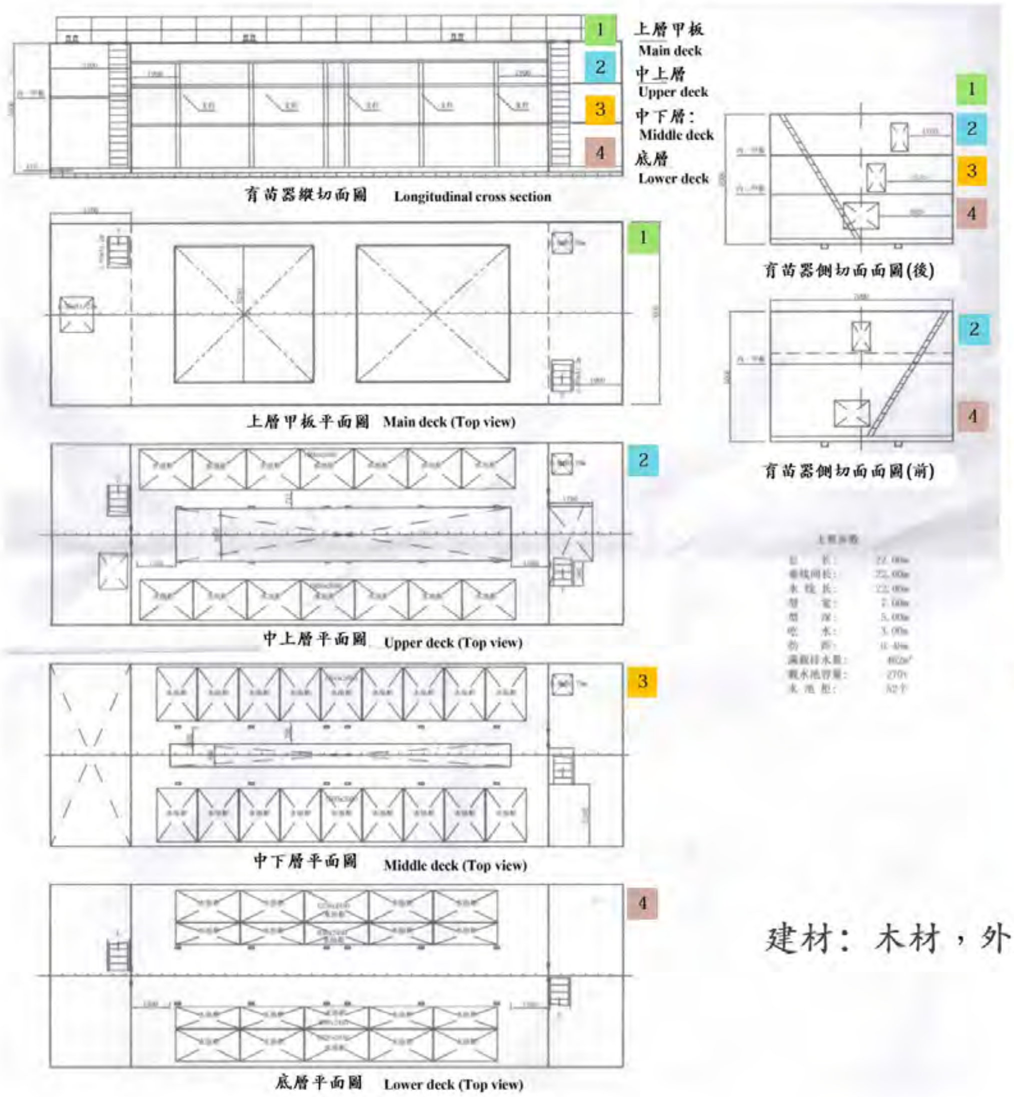
3 裝置設計與結構

育苗器及養魚池

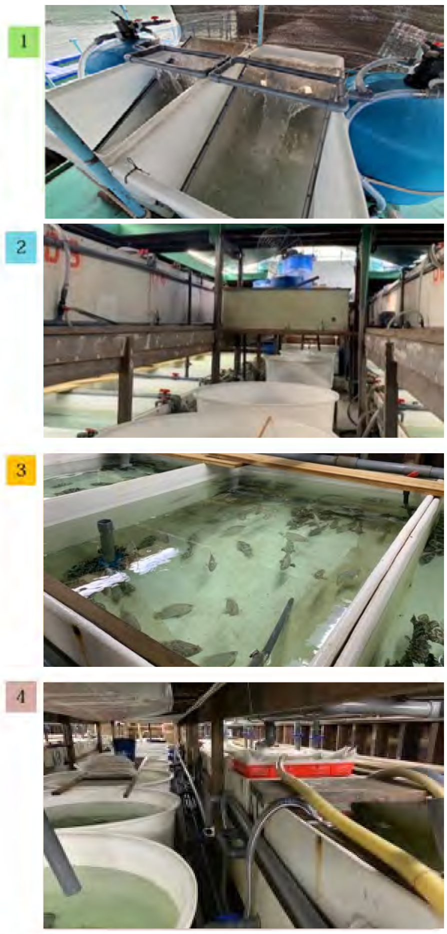
循環海水養殖系統

育苗器及養魚池



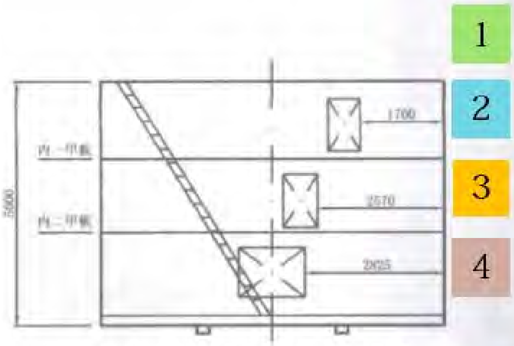


內部分層平面圖

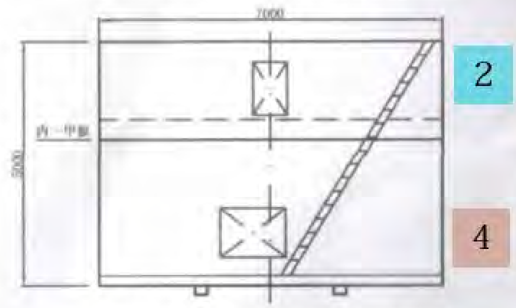


建材：木材，外殼舖上玻璃纖維作放水層。

育苗器及養魚池



育苗器側切面面圖(後)



育苗器側切面面圖(前)

主要参数

总　　长：	22.00m
垂线间长：	22.00m
水 线 长：	22.00m
型　　宽：	7.00m
型　　深：	5.00m
吃　　水：	3.00m
肋　　距：	0.48m
满载排水量：	462m³
鱼水池容量：	270t
水 池 柜：	52个

1

上層甲板：
- 更寮 / 員工休息室；
- 物理濾水裝置包括砂濾器(砂缸)及鋼絲過濾網篩；

2

中上層：
- 14個養魚池(每邊7個，兩邊魚池不相通，各連接獨立過濾系統)；

3

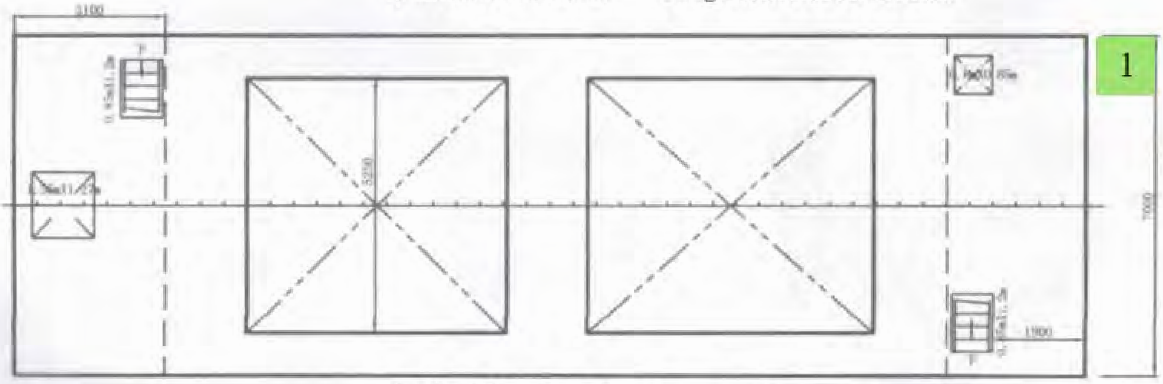
中下層：
- 18個養魚池(每邊9個，兩邊魚池不相通，各連接獨立過濾系統)；

4

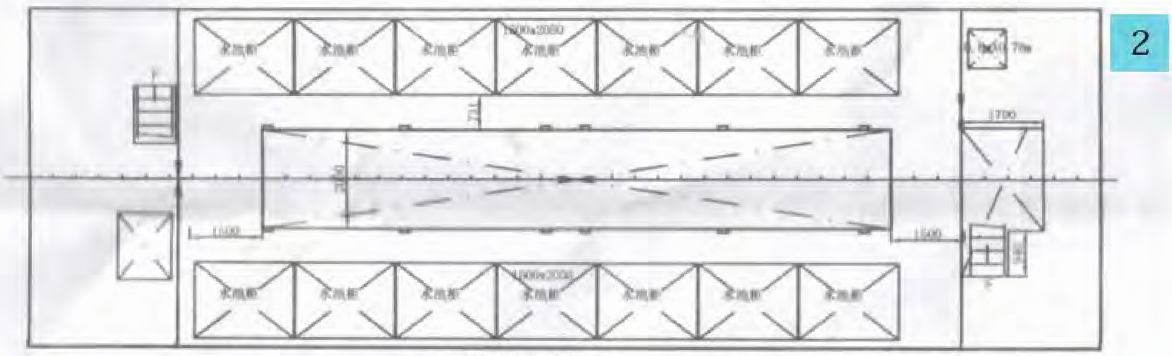
底層：
- 20個生物過濾池及儲水池(每邊10個，兩邊水池不相通，各自獨立運作，連接中上層和中下層同邊魚池)；
- 發電機；
- 電器總制；

建材：木材，外殼鋪上玻璃纖維作放水層。

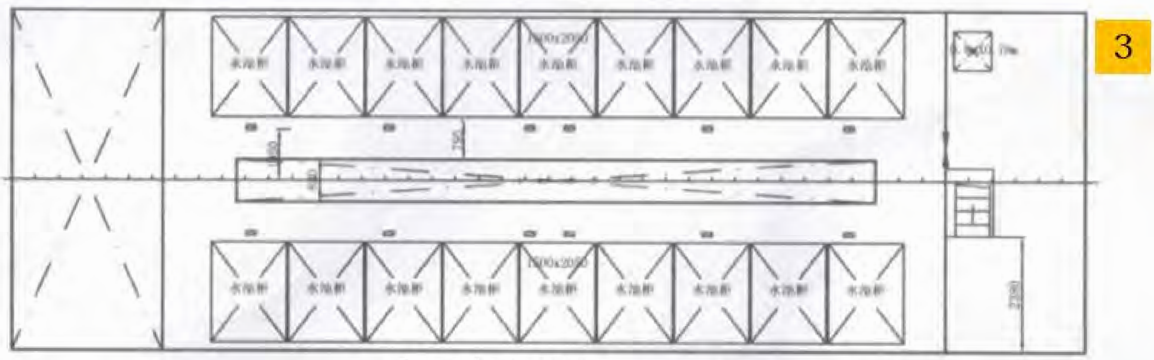
育苗器縱切面圖 Longitudinal cross section



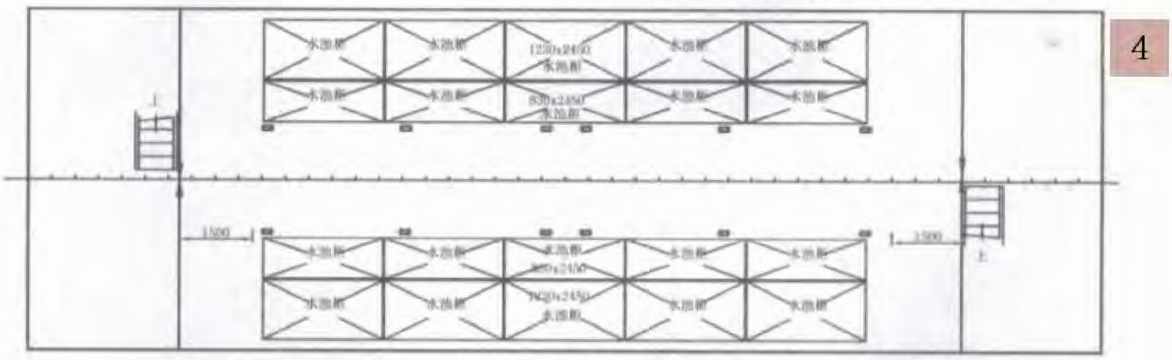
上層甲板平面圖 Main deck (Top view)



中上層平面圖 Upper deck (Top view)



中下層平面圖 Middle deck (Top view)



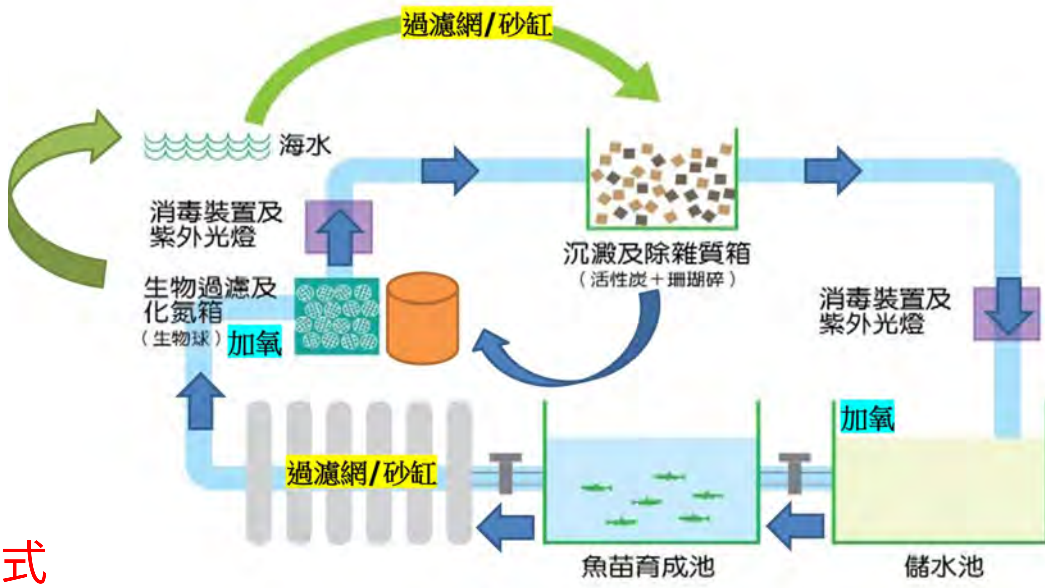
底層平面圖 Lower deck (Top view)

內部分層平面圖

4 循環海水養殖系統

4.1 循環海水養殖系統

多數情況下，養殖池生態體系是封閉的，同時生物密度較高，因此必須應用與之相稱的過濾裝置或過濾系統組合來處理水體，以除去其中的有害物質。選擇循環過濾系統的首要依據是養殖生物的種類、密度以及所需的水質要求。



4.1.1 系統運作模式

循環過濾海水養殖系統 (Recirculating Aquaculature System， RAS) 中有一套維生系統（Life Support System)，是水的處理系統，以維持水生生物生存所需的設備，包括物理過濾裝置(鋼絲網、沙缸)、化氮裝置(蛋白分離器)、臭氧機、增氧機、殺菌系統(紫外光燈) 、生物過濾裝置(硝化反應裝置) 、增氧注射器、儲水缸、供水缸、海水泵、熱泵(水温控制)及其連結的管路(水管及電線)設備等。

循環過濾系統通常可分為三種運作模式 :開放式、封閉式及半封閉式。

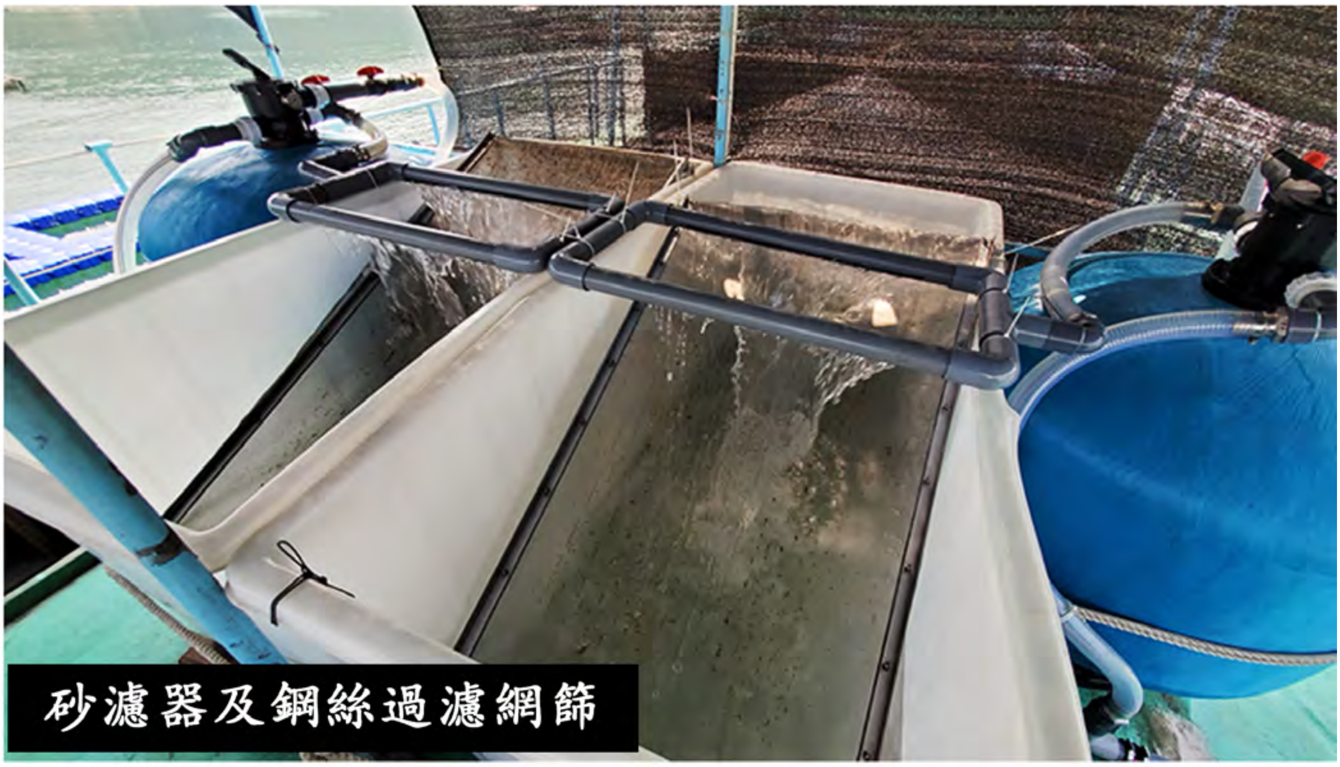
- 開放式系統 :養殖池用水只循環一次，不斷注入已經過濾的新鮮海水；
- 封閉式系統 :用水處理後重回養殖槽，只添加少量的補充水或換水 (如每周約10 - 15%)；
- 半封閉式系統：類似封閉式系統，但其水處理較簡單，換水的次數和水量較大(如每三天約30%)。

我們育苗器中的循環過濾系統，可以按情況隨時切換以上三種運作模式。

4.1.2 系統設備

物理過濾裝置 (Physical filtration)

簡單說就是用來過濾魚的糞便、食物殘渣等物質，擋住這些大顆粒物質達到淨水效果，實物例如砂濾器(砂缸)、鋼絲過濾網篩、過濾棉等等。 砂缸可除去水中大部分沉積物，而鋼絲網篩可過濾不小於150µm的浮游生物。



砂濾器及鋼絲過濾網篩

增氧機 (Oxygen concentrator)

增氧機能以空氣製造純氧。配合文氏管使用，能有效增加海水的溶氧量。

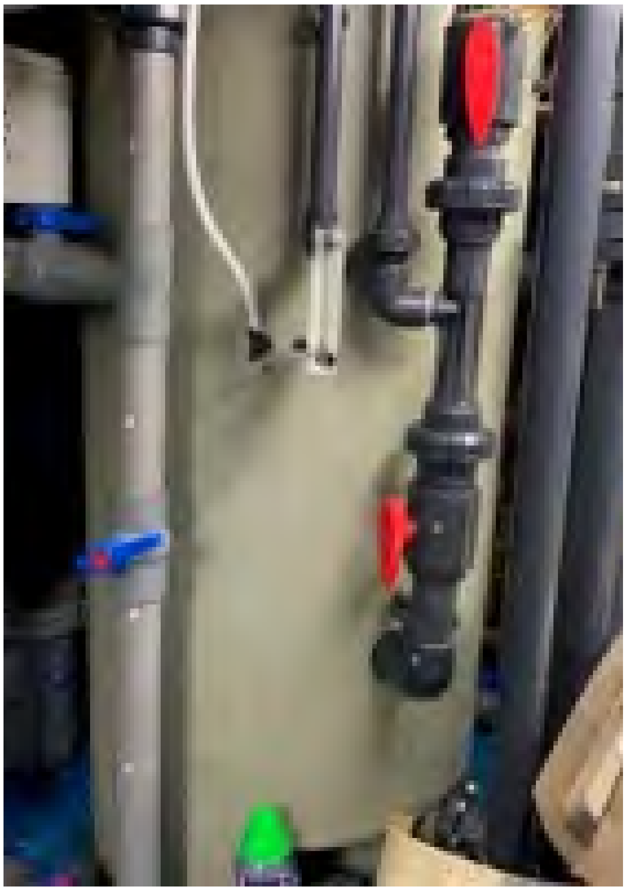
增氧機

氧氣經文氏管注入

蛋白分離器／化氮裝置
(Protein skimmer)

蛋白質分離器又稱為蛋分、蛋白除沫機、化氮裝置，是一種常用於海水魚缸及海水養殖過濾系統中的設備，主要功能是淨化海水。它是利用水中的氣泡表面張力可以吸附混雜在水中的各種顆粒狀的污垢以及可溶性的大分子有機物的原理，採用充氧設備或漩渦泵產生大量的氣泡，這些氣泡全部集中在水面形成泡沫，將吸附了污物的泡沫收集在水面上的容器中，然後就會化為渾濁(咖啡色)的液體被排除。在海水養殖池中，存在著很多有機物，它們來自分解後的魚類中的分秘物、排泄物、殘渣剩食等。蛋白質分離器可以有效地清除水中的有機物顆粒、蛋白質等，能在有機物分解成有毒廢物前將它們分離，達到水質淨化效果，亦有助減輕生物過濾系統的負擔。為了達到更佳的效果，蛋白質分離器通常會同時配合文氏管(Venturi tube) (有時再加上臭氧機或製氧機)使用：水流高壓通過文氏管產生負壓吸氣，在水體中產生大量氣泡，快速去除水中有毒之蛋白質化合物及有機物，稱之為氣浮式蛋白質分離器。

蛋白分離器



紫外光燈 (960W)

紫外線可以消毒海水，殺滅細菌及浮游藻類植物，避免或減少有害細菌及藻類在系統中滋長；紫外線殺菌機燈管材質採紫外線穿透率高的石英玻璃為保護外管，能避免接觸到水。人工波長為253.7nm的紫外線會破壞細菌與病毒的核酸(DNA/RNA)，使其無法繁殖，因此紫外線能有效消滅水中細菌、病毒及單細胞藻類。

臭氧機 (Ozone generator)

臭氧機能以空氣製造臭氧。臭氧作為一種常溫下的氣態強氧化劑，能於短時間內將空氣中或水中的細菌消滅，並能中和、分解毒氣，去除惡臭。臭氧常用於淨化空氣、飲用水、海水、用具。臭氧的滅菌過程屬生物化學氧化反應。臭氧能直接氧化及破壞細菌和病毒的核酸，達到抑制的效果；對各種毒素具有一定的氧化作用，降低其毒性。

注意使用臭氧機的潛在危險：空氣中的臭氧濃度過高，會對眼睛、鼻腔、呼吸道等黏膜造成傷害，如長期處在濃度過高的環境中，還會造成氣管炎、咳嗽、喉嚨疼痛，嚴重時甚至可能引起肺水腫，所以使用時要避免因濃度過高造成的傷害。

臭氧機

水泵

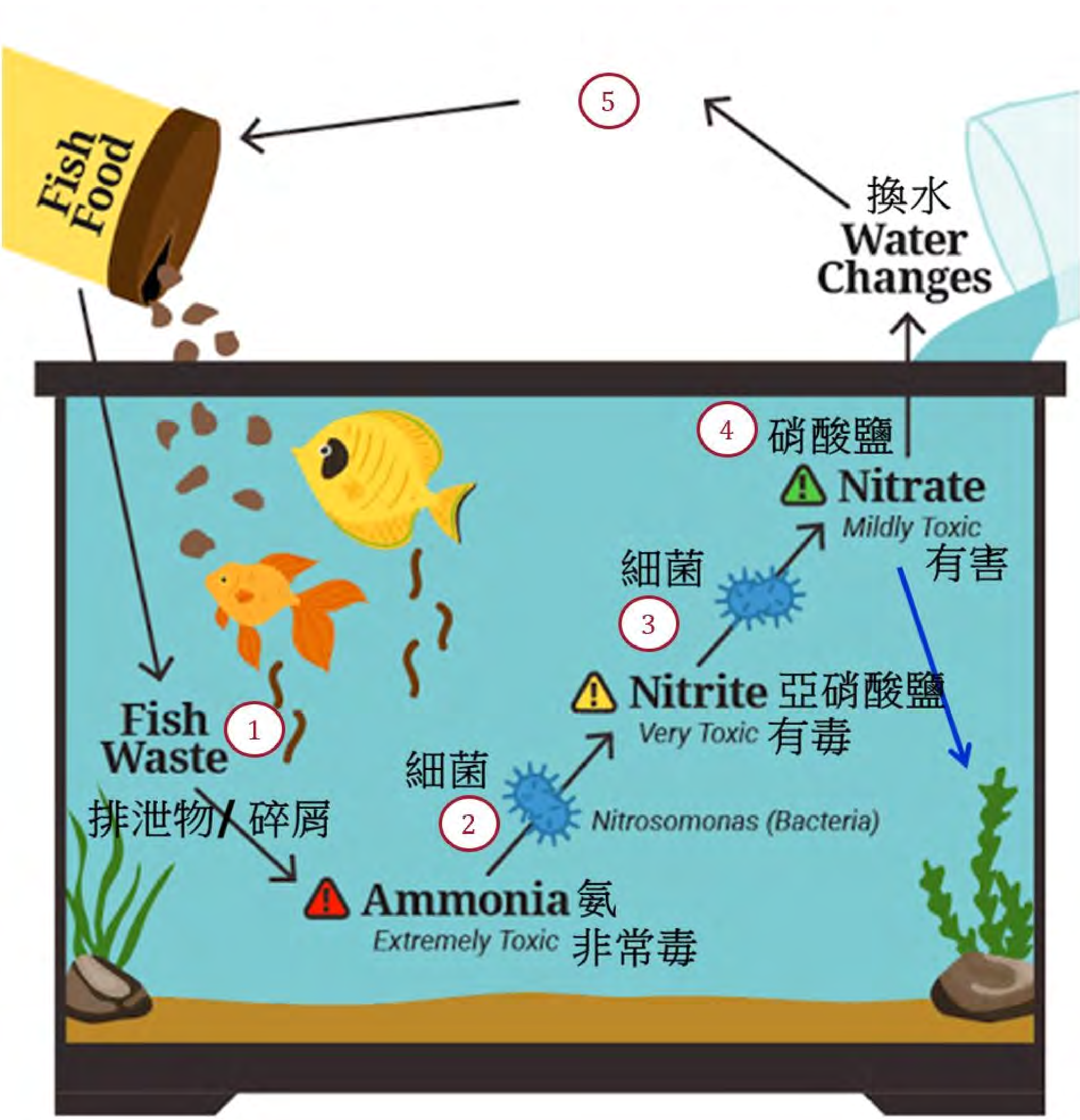
循環海水系統的心臟，負責輸送海水到每一層的養魚池及過濾池，水泵功率輸出越高，可制造水流越快，加快水體交換速度，加快注入帶氧海水，帶走沉漬物及二氧化碳。

生物過濾裝置
(Biological filtration system)

生物過濾裝置，又名硝化反應裝置，簡單說就是在過濾系統中安置生物濾材作為硝化細菌的載體，培養大量硝化細菌。這種濾材是專門為硝化細菌提供一個繁衍場所而設計的，有很大的表面積可供硝化細菌附著。常用生物濾材有生化棉、生化球、生物環(又稱陶瓷環、細菌屋) 、珊瑚石等，它們的共通點是表面積大，適合大量硝化菌居住。另外珊瑚石具持續釋放碳酸鈣的特性，由於含鹼性物質，經過其過濾的pH值一般為7.0～8.5 ，不斷釋放的鈣離子、鎂離子能為海水生物生存提供較高的硬度和穩定的酸鹼度，因而適合用於養殖海水魚的海水過濾系統中。

要理解硝化細菌的作用就要先明白「氮化合物循環」 。→

氮化合物循環



5
Fish Food
換水
Water Changes
4
硝酸鹽
Nitrate
Mildly Toxic
有害
細菌
3
Nitrite 亞硝酸鹽
Very Toxic 有毒
Fish Waste
1
排泄物/碎屑
細菌
2
Nitrosomonas (Bacteria)
Ammonia 氨
Extremely Toxic 非常毒

什麼是「氮化合物循環」?

(1) 魚類的排泄物和吃剩的食物中的蛋白質會被細菌分解，會轉變為氨(俗稱阿摩尼亞)，而氨是有毒的。

(2) 生物過濾物料中生存的硝化細菌，能把氨會轉變為亞硝酸鹽(NO2)；亞硝酸鹽雖然含較少的毒素，但仍對魚類有致命的毒害。

(3) 亞硝酸鹽及後又被第二種硝化細菌轉變為硝酸鹽(NO3)；而這硝酸鹽幾乎是無毒的，但突然或長期暴露在高濃度的硝酸鹽裏是有害的。

(4) 硝酸鹽會被不依附氧氣而生存的細菌(厭氧性細菌)作用變為氮氣而回到大氣中。

(5) 注意，由於厭氧性細菌在循環系統中不容易大量培養，硝酸鹽的濃度通常是靠更換養殖池的水來降低。

化學過濾裝置

主要用於吸附水裡的化學物質，可以去除水質顏色、異味等。常見化學濾材有吸氨石、活性炭、軟水樹脂等。通常在水質有異味、發黃時使用較多，這些濾材具有飽和度，吸收飽滿後就會失去作用，需要更換。

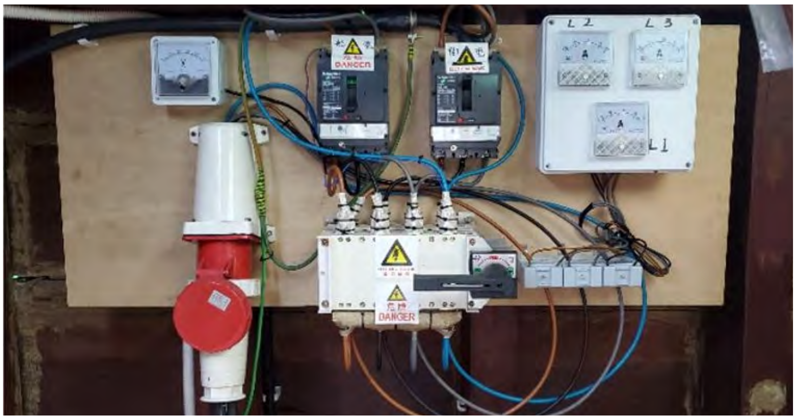
熱交換設備

為維持維生系統海水溫度的利器，可獨立或與空調系統共用，因為在封閉的空間中且運轉的機械也不停的放熱，因此水溫在夏季時會上升，冬天冷天氣會令水溫下降，水温不穩定或忽然改變不利養殖魚生長，熱交換設備如熱泵裝置。

熱泵裝置的工作原理與壓縮式製冷機是一致的，在小型空調器中，為了充分發揮其效能，夏季空調降溫或冬季取暖，都是使用同一套設備來完成。

主要供電設施

- 接駁電覽，從陸上供電到魚排/育苗器
- 100 Amp 三相電力系統
- 電力保護系統



後備供電設施 - 柴油發電機

電力保護系統 - 定期進行電力裝置檢查，確保電力裝置安全可靠

配電系統由不同的電力設備組成，由總配電到最終電路都有不同的電力保護系統 。當電力設施發生故障 (如漏電、過載、短路等)，保護系統便會啟動，跳制將故障隔離，從而達到保護其他正常運作的電力設施，使故障導致的損毀減到最少，避免不必要的電力事故。

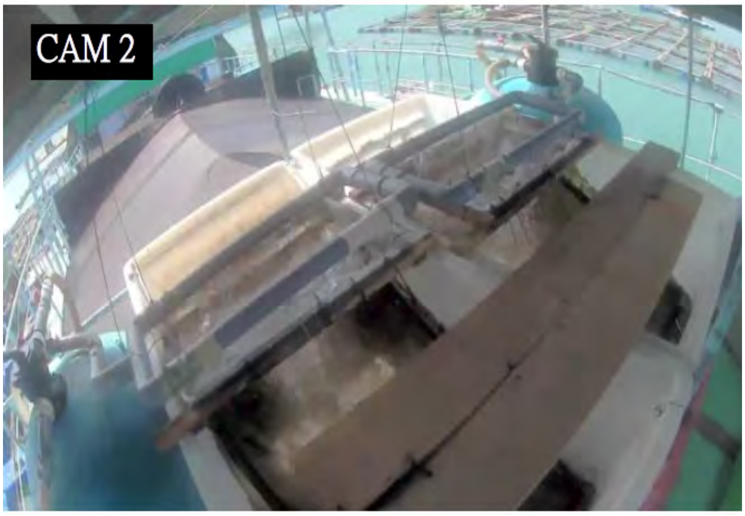
- 電力保護系統必須由合資格的電工施工；
- 各種電氣設備需進行定期檢查，維修保養。

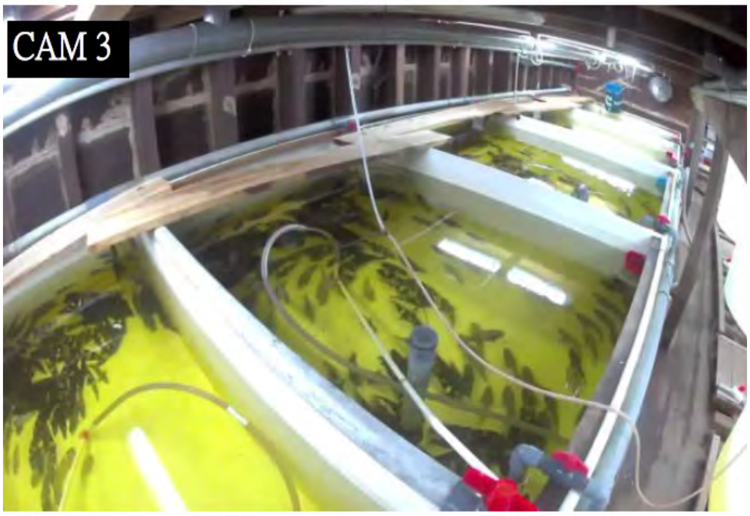
注意，如跳制經常發生或未能識別跳制原因，需由註冊電工對各種電氣設備進行檢查，如發現絶緣損壞和故障，應作出適當的維修或更換。

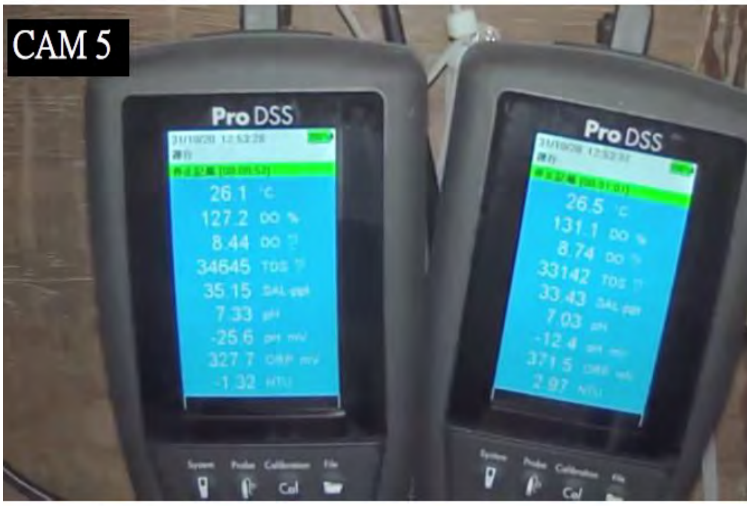
防火及救生設備

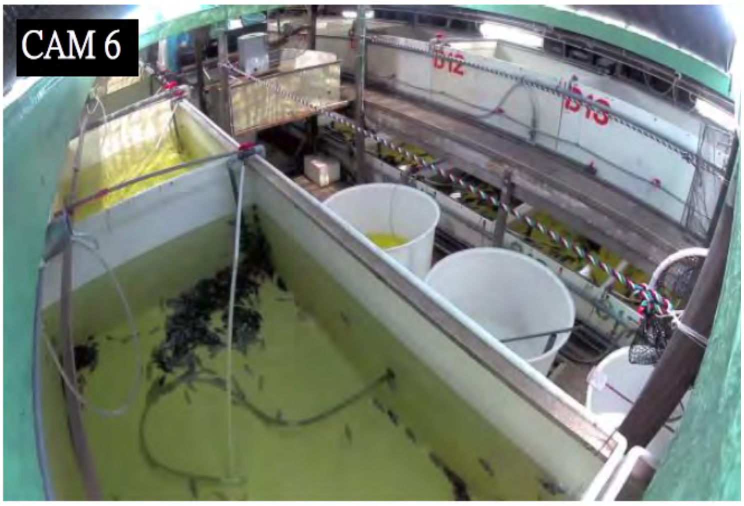
- 育苗器內需裝置防火及救生設備 (如火警偵測器、警報器、滅火器及救生衣等)。 當育苗器發生火警時，防火設備可及時自動提供警示或撲滅火警，提高育苗器的安全；
- 當育苗器發生意外如傾覆、沉沒或火警，育苗器上人員必需撤離或落水時，救生設備提供海上生存，等待救援的機會。

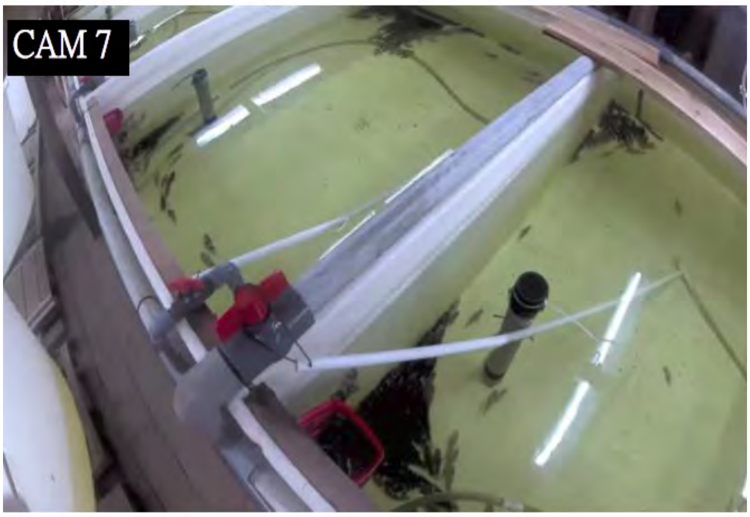
24小時線上影像監察系統











水質監測儀

(YSI ProSS Multiparameter Meter)

每天24小時，每小時記錄水質數據至少6次，包括水溫、溶解氧含量、鹽度、酸鹼度、氧化還原值及渾濁度，確保系統正常運作。

另外，每天要定時，至少兩次，如早上及黃昏或餵飼前後二至三小時，使用快速試紙及測試劑測量氨、亞硝酸鹽及硝酸鹽的含量。

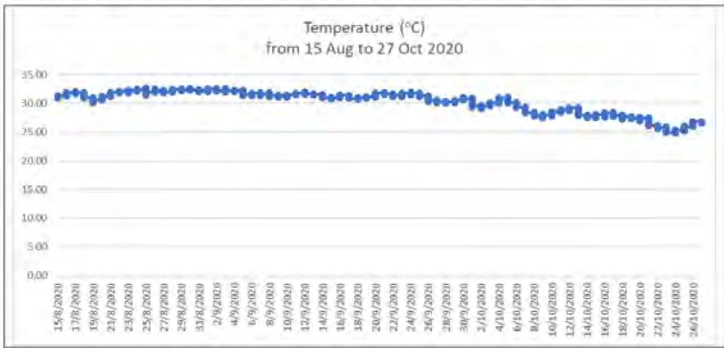


圖 5A：水溫

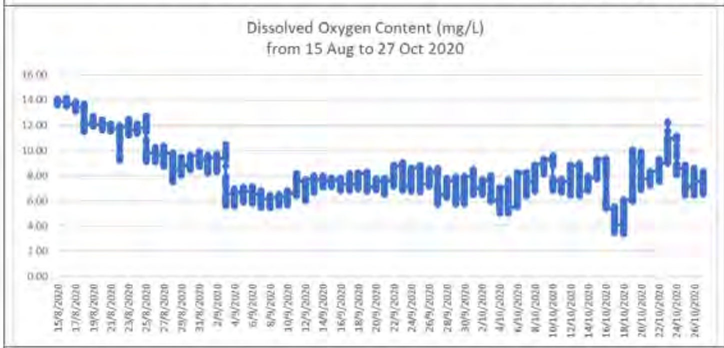


圖 5B：溶解氧含量

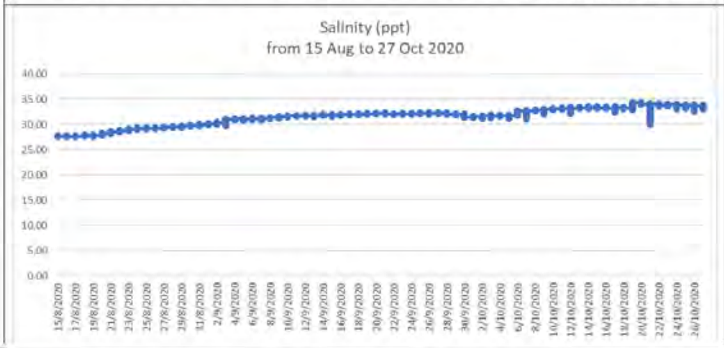


圖 5C：鹽度

圖 5D：酸鹼度

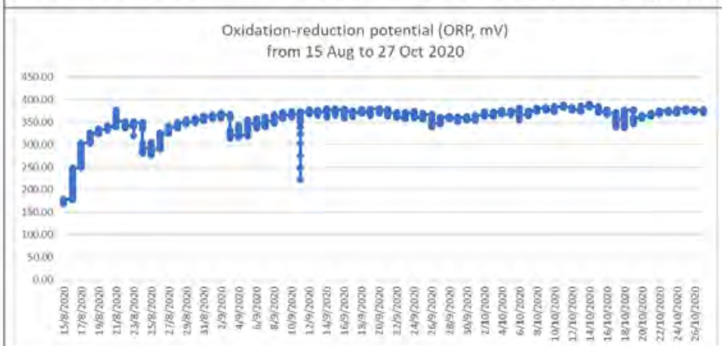


圖 5E：氧化還原電位(ORP)值

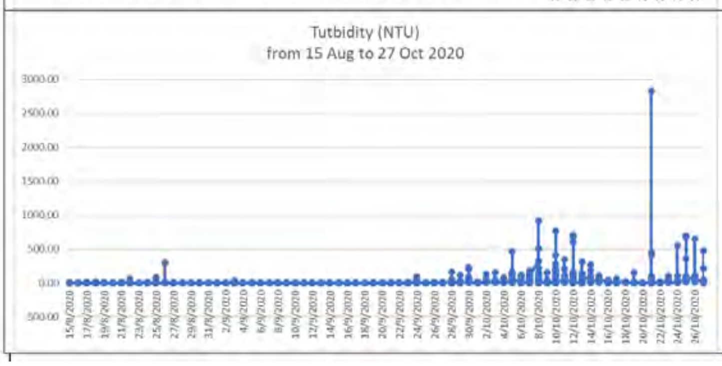


圖 5F：濁度

4.1.3 養魚池設計

來去水設計及位置

建議至少兩個來水口，並以相反方向入水，製造旋渦水流(渦流)，配合中央去水口, 以溢流上排方式，加快排泄物流走的速度，減少排池物在養魚池停留的時間，確保水質清澈。

由於位置所限，我們的育苗器使用長方形養魚池，如情況許可，建議使用圓形或多角形魚池，配合來去水位置，有助製造旋渦水流，可加快排泄物流走及換水速度。

喉管大小

去水喉吋徑必須比來水口大。

水流量

水流量要越高越好，以能提供系統中的生物，魚及硝化細菌新陳代謝作用時所需的溶氧量。

注意事項：由於系統在海上運作，育苗器的整體重量分布會形響育苗器在海面上前後左右的傾斜角度，不平衡會影響養魚池之間或魚池與過濾池之間的來去水流向及速度；必須盡量保持水平，或以預定流向作相對的調整，以平衡及穩定水流方向及速度。

4.1.4 育苗器系統運作

操作日常

每天要定時檢查：每天至少兩次，如早上及黃昏或餵飼前後二至三小時：

1. 檢查水質是否正常；
2. 檢查供電系統及各電器裝置/部件運作正常；
3. 從外觀/游泳姿態監察魚的狀態是否正常；餵飼時，監察魚的食慾是否正常；
4. 並填寫養殖日誌，記錄以上監察情況及日常操作細節，包括餵飼量、換水量，以及各樣正常／異常狀態，包括病魚／死魚數目及處理方法等等(可參考養魚日誌樣版)。

衛生日常

為持環境清潔衛生，避免將細菌帶到育苗器內，每天進入育苗器工作前，必須：

1. 洗手；
2. 消毒雙手；
3. 佩帶口罩；
4. 進入育苗器前，經消毒腳盤消毒雙鞋；
5. 或穿著已消毒的防水手套及水靴；

每天完成工作後，必須將所有工具、防水手套及水靴消毒一次。




4.1.5 養育魚苗

養育魚苗時間表

建議輸入魚苗時間：每年4至8月。

根據過往經驗，由於石斑魚苗如花尾龍躉成長速度快，於春至夏季水溫較高的季節，在育苗器放養兩個月已可以由5-7 cm 成長至12-15 cm，可以轉至海上網箱放養，然後再輸入新一批魚苗在育苗器放養。如此推算，於春至夏季，每兩個月可引入一批，每年共三批魚苗。

養殖系統注意事項

引入魚苗前，需切底清洗消毒系統中的魚池、儲水池，及其他相關設施。然後，先養海水，注入已過濾及消毒的海水，放養小量本地魚種或養殖魚，監察水質變化至少兩星期(包括氨、亞硝酸鹽及硝酸鹽的含量)，待水質穩定及硝化細菌在生物過濾裝置有所增長，氮化合物循環成熟後，才可以開始增加養殖魚數目。

4.1.6 石斑魚飼料

乾式飼料

項目主要採用乾式飼料，與傳統的雜魚飼料相比，乾式飼料有以下好處：

- 乾式飼料有較高的成本效益：根據飼料轉化率的相關研究，如每生產 1 公斤石斑魚只需約 1 - 3 公斤乾式飼料，比雜魚飼料每生產 1 公斤石斑魚需要 6 - 10 公斤雜魚為低，因此雖然每公斤的乾式飼料價格（約港幣 9 元）比雜魚（約港幣 4 元）高，使用乾式飼料的生產成本會相對較低；
- 乾式飼料的成份比較穩定，通常已印於包裝袋上；
- 餵飼乾式飼料可避免石斑魚從雜魚身上感染細菌或寄生蟲的風險；
- 容易進食，殘餘量較少，可減低對環境的影響；
- 可室溫下儲存，容易儲備；
- 供貨和價格較穩定，而雜魚飼料的價格會受天氣或休漁期影響而浮動。

典型石斑魚乾式飼料成份如下：

主要成份	百分比(%)
粗蛋白質 (%)	≥ 46 - 50
粗脂肪 (%)	≥ 4 - 10
水份 (%)	≤ 10
灰份 (%)	≤ 18
粗纖維 (%)	≤ 3

投餵注意事項

投餵前，可先用少量水浸泡乾式飼料顆粒約五至十分鐘以吸收適量水份，使其較容易讓魚消化。期間亦可添加適量維生素和益生菌，維生素能增強石斑魚的抵抗力，益生菌能改善腸道健康，幫助消化和吸收。

如何根據魚的重量計算每天的投餵量？

在不同季節的平均海水溫度下，每天投餵率 (= 魚平均重量百分比) 或每 100 公斤魚該餵食的飼料總量如下：

		每天投餵率 (%)	
魚平均重量 (克)	飼料大小 (毫米)	夏季 (26 ºC)	冬季 (18 ºC)
20 - 50	3	2.8 – 3.0	1.2 – 1.4
50 - 100	3	2.2 – 2.4	0.9 - 1.2
100 - 200	4 - 6	1.6 – 1.8	0.7 - 0.9
200 - 400	4 - 6	1.2 – 1.4	0.5 – 0.7
400 - 600	6 - 8	1.0 – 1.2	0.4 – 0.6
> 600	8 - 11	0.8 – 1.0	0.3 – 0.5

公式：

乾式飼料用量 (克) = (網箱或魚缸中的魚數) x (魚的平均體重) x (% 每天投餵率)

(注意：以上資料表及公式只供參考，投餵量應根據個別情況作調整。)

例子(1)：

假設在夏季，有400 條石斑魚在一個魚池裡，平均體重 20 克，根據上表，飼料的每天投餵率約為魚體重2.8 - 3.0 %。以3.0 %計算，
每天該餵食的飼料總量 = 400 條 x 20 克 x 3.0 % = 240 克

投餵注意事項

- 對於體型較小的石斑魚（< 100 克），每天的餵食次數可以是每天 2 或 3 次，因為它的胃相對較小，但消化/代謝速度很快。如果每天餵魚3次，每天240 克的總量可以分成3等份，每次餵80 克飼料。每次慢慢加入飼料，讓所有魚吃飽。
- 避免在中午或午後投餵，以免陽光直射，因為石斑魚會因躲避強光而減少進食。

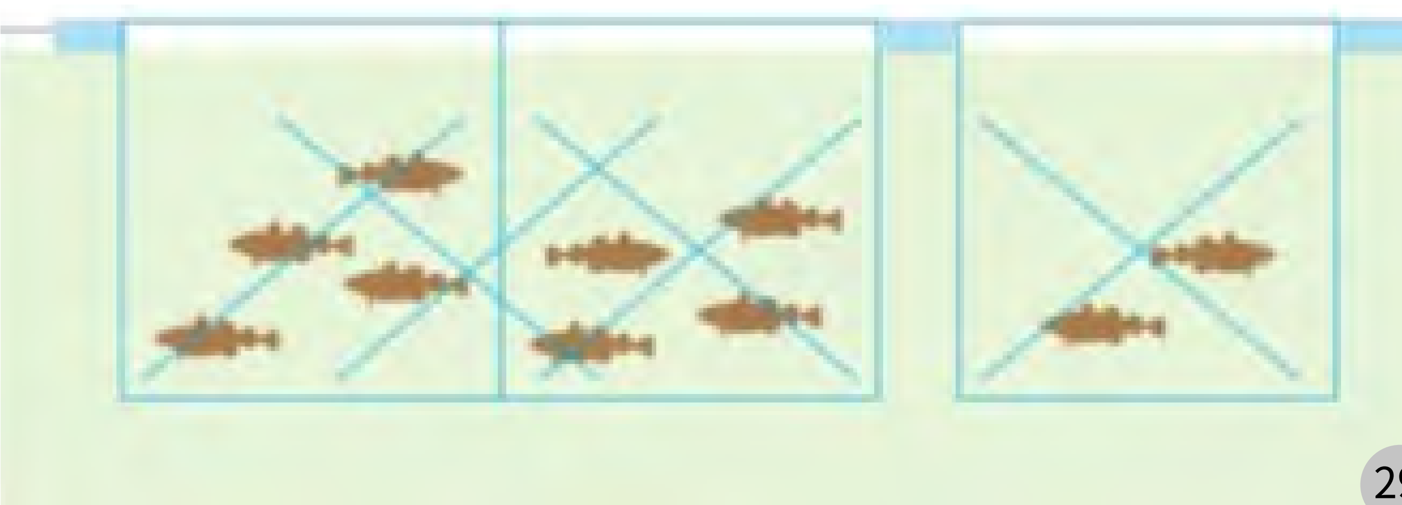
例子(2)：

假設在夏季，有400 條石斑魚在一個籠子裡，平均體重 600 克，根據上表，飼料的每天投餵率約為魚體重1.0 - 1.2 %。以1.2 %計算，
每天該餵食的飼料總量 = 400 條 x 600 克 x 1.2 % = 2,880 克

4.1.7 成魚養殖 - 立方浮筒組成的新型養殖網箱

與傳統養殖網箱比較，新型網箱有以下好處：

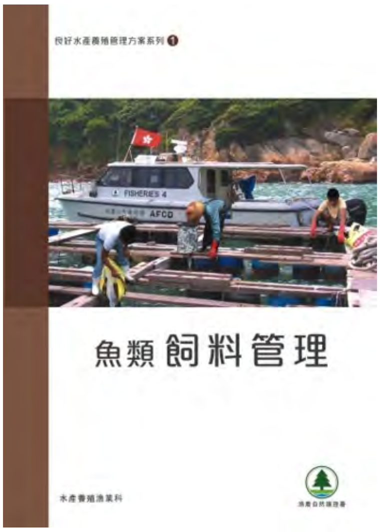
- 高承載力：每平方公尺可承載360公斤的重量。
- 多用途：可廣泛地運用於各種水域。
- 經濟實惠：幾乎不需任何保養維修費用。
- 強耐性：防紫外線、抗海水、防化學藥劑、油漬等之侵蝕。
- 機動可變性：一個連接栓可支撐四個浮筒；以此擴充，可依需要而變化，組合成任何尺寸和任何結構之設施。

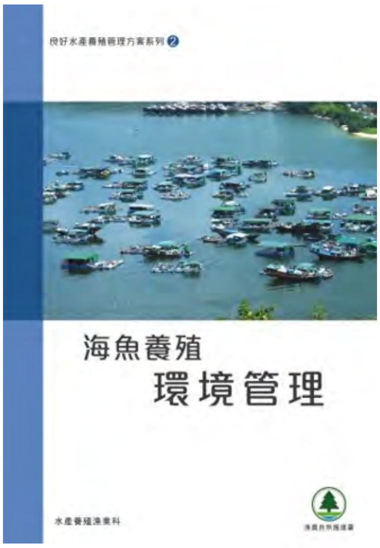


4.1.8 其他養育魚苗及成魚的注意事項

建議參考漁農自然護理署的良好水產養殖管理方案系列中的：

- 方案 1：魚類養殖飼料管理
  (https://www.hkaffs.org/tc_chi/files/GAP1_tc.pdf)
- 方案 2：海魚養殖環境管理
  (https://www.hkaffs.org/tc_chi/files/GAP2_tc.pdf)
- 方案 4：養殖魚類疾病的防治
  (https://www.hkaffs.org/tc_chi/files/GAP4_tc.pdf)
- 方案 5：魚苗養殖健康管理
  (https://www.hkaffs.org/tc_chi/files/GAP5_tc.pdf)





5 養魚日誌樣版

- (1)魚苗種類紀錄表
- (2) 飼料投餵/魚苗健康紀錄表
- (3) 水質檢驗及監測紀錄表
- (4) 耗材/消耗品管理紀錄表
- (5) 魚苗成長/銷售紀錄表

(1)魚苗種類紀錄表

項目名稱	SFDF-0016								
來貨日期	苗種名稱	供應商	體型大小	進魚數量(尾)	單價(元)	來貨成本(元)	來源地	苗種批號	備註
年 月 日									
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(2a)飼料投餵/魚苗健康紀錄表(養魚缸)

苗種批號:	
飼料種類/代碼:	

漁護署藥浴指引:

藥品	使用守則
福爾馬林（[illegible]）	用1:10,000福爾馬林溶液（[illegible]）進行1小時藥浴。有需要時可將濃度提升至1:4,000（[illegible]）。不可使用有白色沉澱物的福爾馬林溶液。
高錳酸鉀（[illegible]）	用1:250,000高錳酸鉀（[illegible]）進行1-3小時藥浴。長期藥浴則用1:400,000高錳酸鉀（[illegible]）浸泡24小時。
雙氧水	用1:2,000 30%雙氧水（[illegible]）進行1小時藥浴。

項目名稱	SFDF-0016

日期 (時間)	位置	投餵量(公斤)	魚苗進食情況	魚苗游泳習性	異常情況	魚病防治/疏養	浸浴/餵藥方法 (用量見備註)	備註
年 月 日 (:)			☐正常 ☐異常->檢查魚身/鰓; 異常魚缸/魚數:______	☐正常 ☐異常->檢查魚身/鰓; 異常魚缸/魚數:______	☐傷口/潰瘍 ☐體色變黑 ☐寄生蟲 ☐白色塊狀 ☐出血 ☐其他:______	☐浸浴 ☐疏養 ☐餵藥 ☐隔離 ☐獸醫/漁護署	☐淡水 ☐福爾馬林 ☐雙氧水 ☐高錳酸鉀 ☐其他:______	☐清除死魚:____尾 ☐隔離病魚:____尾 ☐其他:______
年 月 日 (:)			☐正常 ☐異常->檢查魚身/鰓; 異常魚缸/魚數:______	☐正常 ☐異常->檢查魚身/鰓; 異常魚缸/魚數:______	☐傷口/潰瘍 ☐體色變黑 ☐寄生蟲 ☐白色塊狀 ☐出血 ☐其他:______	☐浸浴 ☐疏養 ☐餵藥 ☐隔離 ☐獸醫/漁護署	☐淡水 ☐福爾馬林 ☐雙氧水 ☐高錳酸鉀 ☐其他:______	☐清除死魚:____尾 ☐隔離病魚:____尾 ☐其他:______
年 月 日 (:)			☐正常 ☐異常->檢查魚身/鰓; 異常魚缸/魚數:______	☐正常 ☐異常->檢查魚身/鰓; 異常魚缸/魚數:______	☐傷口/潰瘍 ☐體色變黑 ☐寄生蟲 ☐白色塊狀 ☐出血 ☐其他:______	☐浸浴 ☐疏養 ☐餵藥 ☐隔離 ☐獸醫/漁護署	☐淡水 ☐福爾馬林 ☐雙氧水 ☐高錳酸鉀 ☐其他:______	☐清除死魚:____尾 ☐隔離病魚:____尾 ☐其他:______
年 月 日 (:)			☐正常 ☐異常->檢查魚身/鰓; 異常魚缸/魚數:______	☐正常 ☐異常->檢查魚身/鰓; 異常魚缸/魚數:______	☐傷口/潰瘍 ☐體色變黑 ☐寄生蟲 ☐白色塊狀 ☐出血 ☐其他:______	☐浸浴 ☐疏養 ☐餵藥 ☐隔離 ☐獸醫/漁護署	☐淡水 ☐福爾馬林 ☐雙氧水 ☐高錳酸鉀 ☐其他:______	☐清除死魚:____尾 ☐隔離病魚:____尾 ☐其他:______
年 月 日 (:)			☐正常 ☐異常->檢查魚身/鰓; 異常魚缸/魚數:______	☐正常 ☐異常->檢查魚身/鰓; 異常魚缸/魚數:______	☐傷口/潰瘍 ☐體色變黑 ☐寄生蟲 ☐白色塊狀 ☐出血 ☐其他:______	☐浸浴 ☐疏養 ☐餵藥 ☐隔離 ☐獸醫/漁護署	☐淡水 ☐福爾馬林 ☐雙氧水 ☐高錳酸鉀 ☐其他:______	☐清除死魚:____尾 ☐隔離病魚:____尾 ☐其他:______
年 月 日 (:)			☐正常 ☐異常->檢查魚身/鰓; 異常魚缸/魚數:______	☐正常 ☐異常->檢查魚身/鰓; 異常魚缸/魚數:______	☐傷口/潰瘍 ☐體色變黑 ☐寄生蟲 ☐白色塊狀 ☐出血 ☐其他:______	☐浸浴 ☐疏養 ☐餵藥 ☐隔離 ☐獸醫/漁護署	☐淡水 ☐福爾馬林 ☐雙氧水 ☐高錳酸鉀 ☐其他:______	☐清除死魚:____尾 ☐隔離病魚:____尾 ☐其他:______
年 月 日 (:)			☐正常 ☐異常->檢查魚身/鰓; 異常魚缸/魚數:______	☐正常 ☐異常->檢查魚身/鰓; 異常魚缸/魚數:______	☐傷口/潰瘍 ☐體色變黑 ☐寄生蟲 ☐白色塊狀 ☐出血 ☐其他:______	☐浸浴 ☐疏養 ☐餵藥 ☐隔離 ☐獸醫/漁護署	☐淡水 ☐福爾馬林 ☐雙氧水 ☐高錳酸鉀 ☐其他:______	☐清除死魚:____尾 ☐隔離病魚:____尾 ☐其他:______
年 月 日 (:)			☐正常 ☐異常->檢查魚身/鰓; 異常魚缸/魚數:______	☐正常 ☐異常->檢查魚身/鰓; 異常魚缸/魚數:______	☐傷口/潰瘍 ☐體色變黑 ☐寄生蟲 ☐白色塊狀 ☐出血 ☐其他:______	☐浸浴 ☐疏養 ☐餵藥 ☐隔離 ☐獸醫/漁護署	☐淡水 ☐福爾馬林 ☐雙氧水 ☐高錳酸鉀 ☐其他:______	☐清除死魚:____尾 ☐隔離病魚:____尾 ☐其他:______
年 月 日 (:)			☐正常 ☐異常->檢查魚身/鰓; 異常魚缸/魚數:______	☐正常 ☐異常->檢查魚身/鰓; 異常魚缸/魚數:______	☐傷口/潰瘍 ☐體色變黑 ☐寄生蟲 ☐白色塊狀 ☐出血 ☐其他:______	☐浸浴 ☐疏養 ☐餵藥 ☐隔離 ☐獸醫/漁護署	☐淡水 ☐福爾馬林 ☐雙氧水 ☐高錳酸鉀 ☐其他:______	☐清除死魚:____尾 ☐隔離病魚:____尾 ☐其他:______
年 月 日 (:)			☐正常 ☐異常->檢查魚身/鰓; 異常魚缸/魚數:______	☐正常 ☐異常->檢查魚身/鰓; 異常魚缸/魚數:______	☐傷口/潰瘍 ☐體色變黑 ☐寄生蟲 ☐白色塊狀 ☐出血 ☐其他:______	☐浸浴 ☐疏養 ☐餵藥 ☐隔離 ☐獸醫/漁護署	☐淡水 ☐福爾馬林 ☐雙氧水 ☐高錳酸鉀 ☐其他:______	☐清除死魚:____尾 ☐隔離病魚:____尾 ☐其他:______
年 月 日 (:)			☐正常 ☐異常->檢查魚身/鰓; 異常魚缸/魚數:______	☐正常 ☐異常->檢查魚身/鰓; 異常魚缸/魚數:______	☐傷口/潰瘍 ☐體色變黑 ☐寄生蟲 ☐白色塊狀 ☐出血 ☐其他:______	☐浸浴 ☐疏養 ☐餵藥 ☐隔離 ☐獸醫/漁護署	☐淡水 ☐福爾馬林 ☐雙氧水 ☐高錳酸鉀 ☐其他:______	☐清除死魚:____尾 ☐隔離病魚:____尾 ☐其他:______
年 月 日 (:)			☐正常 ☐異常->檢查魚身/鰓; 異常魚缸/魚數:______	☐正常 ☐異常->檢查魚身/鰓; 異常魚缸/魚數:______	☐傷口/潰瘍 ☐體色變黑 ☐寄生蟲 ☐白色塊狀 ☐出血 ☐其他:______	☐浸浴 ☐疏養 ☐餵藥 ☐隔離 ☐獸醫/漁護署	☐淡水 ☐福爾馬林 ☐雙氧水 ☐高錳酸鉀 ☐其他:______	☐清除死魚:____尾 ☐隔離病魚:____尾 ☐其他:______
年 月 日 (:)			☐正常 ☐異常->檢查魚身/鰓; 異常魚缸/魚數:______	☐正常 ☐異常->檢查魚身/鰓; 異常魚缸/魚數:______	☐傷口/潰瘍 ☐體色變黑 ☐寄生蟲 ☐白色塊狀 ☐出血 ☐其他:______	☐浸浴 ☐疏養 ☐餵藥 ☐隔離 ☐獸醫/漁護署	☐淡水 ☐福爾馬林 ☐雙氧水 ☐高錳酸鉀 ☐其他:______	☐清除死魚:____尾 ☐隔離病魚:____尾 ☐其他:______

(2b)飼料投餵/魚苗健康紀錄表(網箱)

苗種批號:	
飼料種類/代碼:	

漁護署藥浴指引:

藥品	使用守則	藥品	使用守則
福爾馬林	用1:10,000福爾馬林溶液，進行1小時藥浴。有需要時可將濃度提升至1:4,000。不可使用有白色沉澱物的福爾馬林溶液。	高錳酸鉀	用1:250,000高錳酸鉀進行1-3小時藥浴。長期藥浴則用1:400,000高錳酸鉀浸泡24小時。
		雙氧水	用1:2,000 30%雙氧水進行1小時藥浴。

項目名稱	SFDF-0016

日期 (時間)	位置	投餵量(公斤)	魚苗進食情況	魚苗游泳習性	異常情況	魚病防治/疏養	浸浴/餵藥方法 (用量見備註)	備註
年 月 日 (:)			☐正常 ☐異常->檢查魚身/鰓; 異常魚缸/魚數:______	☐正常 ☐異常->檢查魚身/鰓; 異常魚缸/魚數:______	☐傷口/潰瘍 ☐體色變黑 ☐寄生蟲 ☐白色塊狀 ☐出血 ☐其他:______	☐浸浴 ☐疏養 ☐餵藥 ☐隔離 ☐獸醫/漁護署	☐淡水 ☐福爾馬林 ☐雙氧水 ☐高錳酸鉀 ☐其他:______	☐清除死魚:____尾 ☐隔離病魚:____尾 ☐其他:______
年 月 日 (:)			☐正常 ☐異常->檢查魚身/鰓; 異常魚缸/魚數:______	☐正常 ☐異常->檢查魚身/鰓; 異常魚缸/魚數:______	☐傷口/潰瘍 ☐體色變黑 ☐寄生蟲 ☐白色塊狀 ☐出血 ☐其他:______	☐浸浴 ☐疏養 ☐餵藥 ☐隔離 ☐獸醫/漁護署	☐淡水 ☐福爾馬林 ☐雙氧水 ☐高錳酸鉀 ☐其他:______	☐清除死魚:____尾 ☐隔離病魚:____尾 ☐其他:______
年 月 日 (:)			☐正常 ☐異常->檢查魚身/鰓; 異常魚缸/魚數:______	☐正常 ☐異常->檢查魚身/鰓; 異常魚缸/魚數:______	☐傷口/潰瘍 ☐體色變黑 ☐寄生蟲 ☐白色塊狀 ☐出血 ☐其他:______	☐浸浴 ☐疏養 ☐餵藥 ☐隔離 ☐獸醫/漁護署	☐淡水 ☐福爾馬林 ☐雙氧水 ☐高錳酸鉀 ☐其他:______	☐清除死魚:____尾 ☐隔離病魚:____尾 ☐其他:______
年 月 日 (:)			☐正常 ☐異常->檢查魚身/鰓; 異常魚缸/魚數:______	☐正常 ☐異常->檢查魚身/鰓; 異常魚缸/魚數:______	☐傷口/潰瘍 ☐體色變黑 ☐寄生蟲 ☐白色塊狀 ☐出血 ☐其他:______	☐浸浴 ☐疏養 ☐餵藥 ☐隔離 ☐獸醫/漁護署	☐淡水 ☐福爾馬林 ☐雙氧水 ☐高錳酸鉀 ☐其他:______	☐清除死魚:____尾 ☐隔離病魚:____尾 ☐其他:______
年 月 日 (:)			☐正常 ☐異常->檢查魚身/鰓; 異常魚缸/魚數:______	☐正常 ☐異常->檢查魚身/鰓; 異常魚缸/魚數:______	☐傷口/潰瘍 ☐體色變黑 ☐寄生蟲 ☐白色塊狀 ☐出血 ☐其他:______	☐浸浴 ☐疏養 ☐餵藥 ☐隔離 ☐獸醫/漁護署	☐淡水 ☐福爾馬林 ☐雙氧水 ☐高錳酸鉀 ☐其他:______	☐清除死魚:____尾 ☐隔離病魚:____尾 ☐其他:______
年 月 日 (:)			☐正常 ☐異常->檢查魚身/鰓; 異常魚缸/魚數:______	☐正常 ☐異常->檢查魚身/鰓; 異常魚缸/魚數:______	☐傷口/潰瘍 ☐體色變黑 ☐寄生蟲 ☐白色塊狀 ☐出血 ☐其他:______	☐浸浴 ☐疏養 ☐餵藥 ☐隔離 ☐獸醫/漁護署	☐淡水 ☐福爾馬林 ☐雙氧水 ☐高錳酸鉀 ☐其他:______	☐清除死魚:____尾 ☐隔離病魚:____尾 ☐其他:______
年 月 日 (:)			☐正常 ☐異常->檢查魚身/鰓; 異常魚缸/魚數:______	☐正常 ☐異常->檢查魚身/鰓; 異常魚缸/魚數:______	☐傷口/潰瘍 ☐體色變黑 ☐寄生蟲 ☐白色塊狀 ☐出血 ☐其他:______	☐浸浴 ☐疏養 ☐餵藥 ☐隔離 ☐獸醫/漁護署	☐淡水 ☐福爾馬林 ☐雙氧水 ☐高錳酸鉀 ☐其他:______	☐清除死魚:____尾 ☐隔離病魚:____尾 ☐其他:______
年 月 日 (:)			☐正常 ☐異常->檢查魚身/鰓; 異常魚缸/魚數:______	☐正常 ☐異常->檢查魚身/鰓; 異常魚缸/魚數:______	☐傷口/潰瘍 ☐體色變黑 ☐寄生蟲 ☐白色塊狀 ☐出血 ☐其他:______	☐浸浴 ☐疏養 ☐餵藥 ☐隔離 ☐獸醫/漁護署	☐淡水 ☐福爾馬林 ☐雙氧水 ☐高錳酸鉀 ☐其他:______	☐清除死魚:____尾 ☐隔離病魚:____尾 ☐其他:______
年 月 日 (:)			☐正常 ☐異常->檢查魚身/鰓; 異常魚缸/魚數:______	☐正常 ☐異常->檢查魚身/鰓; 異常魚缸/魚數:______	☐傷口/潰瘍 ☐體色變黑 ☐寄生蟲 ☐白色塊狀 ☐出血 ☐其他:______	☐浸浴 ☐疏養 ☐餵藥 ☐隔離 ☐獸醫/漁護署	☐淡水 ☐福爾馬林 ☐雙氧水 ☐高錳酸鉀 ☐其他:______	☐清除死魚:____尾 ☐隔離病魚:____尾 ☐其他:______
年 月 日 (:)			☐正常 ☐異常->檢查魚身/鰓; 異常魚缸/魚數:______	☐正常 ☐異常->檢查魚身/鰓; 異常魚缸/魚數:______	☐傷口/潰瘍 ☐體色變黑 ☐寄生蟲 ☐白色塊狀 ☐出血 ☐其他:______	☐浸浴 ☐疏養 ☐餵藥 ☐隔離 ☐獸醫/漁護署	☐淡水 ☐福爾馬林 ☐雙氧水 ☐高錳酸鉀 ☐其他:______	☐清除死魚:____尾 ☐隔離病魚:____尾 ☐其他:______
年 月 日 (:)			☐正常 ☐異常->檢查魚身/鰓; 異常魚缸/魚數:______	☐正常 ☐異常->檢查魚身/鰓; 異常魚缸/魚數:______	☐傷口/潰瘍 ☐體色變黑 ☐寄生蟲 ☐白色塊狀 ☐出血 ☐其他:______	☐浸浴 ☐疏養 ☐餵藥 ☐隔離 ☐獸醫/漁護署	☐淡水 ☐福爾馬林 ☐雙氧水 ☐高錳酸鉀 ☐其他:______	☐清除死魚:____尾 ☐隔離病魚:____尾 ☐其他:______
年 月 日 (:)			☐正常 ☐異常->檢查魚身/鰓; 異常魚缸/魚數:______	☐正常 ☐異常->檢查魚身/鰓; 異常魚缸/魚數:______	☐傷口/潰瘍 ☐體色變黑 ☐寄生蟲 ☐白色塊狀 ☐出血 ☐其他:______	☐浸浴 ☐疏養 ☐餵藥 ☐隔離 ☐獸醫/漁護署	☐淡水 ☐福爾馬林 ☐雙氧水 ☐高錳酸鉀 ☐其他:______	☐清除死魚:____尾 ☐隔離病魚:____尾 ☐其他:______
年 月 日 (:)			☐正常 ☐異常->檢查魚身/鰓; 異常魚缸/魚數:______	☐正常 ☐異常->檢查魚身/鰓; 異常魚缸/魚數:______	☐傷口/潰瘍 ☐體色變黑 ☐寄生蟲 ☐白色塊狀 ☐出血 ☐其他:______	☐浸浴 ☐疏養 ☐餵藥 ☐隔離 ☐獸醫/漁護署	☐淡水 ☐福爾馬林 ☐雙氧水 ☐高錳酸鉀 ☐其他:______	☐清除死魚:____尾 ☐隔離病魚:____尾 ☐其他:______

(3)水質檢驗及監測紀錄表

項目名稱	SFDF-0016

日期 (時間)	位置	水溫(℃)	溶氧 (%; mg/L)	鹽度(ppt)	pH	ORP(mV)	濁度(NTU)	透明度	其他指標(快速測試套件)			備註
									總氨氮/TAN (ppm)	亞硝酸/NO_2^- (ppm)	硝酸鹽/NO_3^- (ppm)	
年 月 日 (:)								□清澈 □帶白色 □混濁 □其他	□0 □≤0.5 □≤1 □>1-2	□0 □≤0.5 □≤1 □>1-4	□0 □≤10 □≤50 □>50	
								□清澈 □帶白色 □混濁 □其他	□0 □≤0.5 □≤1 □>1-2	□0 □≤0.5 □≤1 □>1-4	□0 □≤10 □≤50 □>50	
年 月 日 (:)								□清澈 □帶白色 □混濁 □其他	□0 □≤0.5 □≤1 □>1-2	□0 □≤0.5 □≤1 □>1-4	□0 □≤10 □≤50 □>50	
								□清澈 □帶白色 □混濁 □其他	□0 □≤0.5 □≤1 □>1-2	□0 □≤0.5 □≤1 □>1-4	□0 □≤10 □≤50 □>50	
年 月 日 (:)								□清澈 □帶白色 □混濁 □其他	□0 □≤0.5 □≤1 □>1-2	□0 □≤0.5 □≤1 □>1-4	□0 □≤10 □≤50 □>50	
								□清澈 □帶白色 □混濁 □其他	□0 □≤0.5 □≤1 □>1-2	□0 □≤0.5 □≤1 □>1-4	□0 □≤10 □≤50 □>50	
年 月 日 (:)								□清澈 □帶白色 □混濁 □其他	□0 □≤0.5 □≤1 □>1-2	□0 □≤0.5 □≤1 □>1-4	□0 □≤10 □≤50 □>50	
								□清澈 □帶白色 □混濁 □其他	□0 □≤0.5 □≤1 □>1-2	□0 □≤0.5 □≤1 □>1-4	□0 □≤10 □≤50 □>50	
年 月 日 (:)								□清澈 □帶白色 □混濁 □其他	□0 □≤0.5 □≤1 □>1-2	□0 □≤0.5 □≤1 □>1-4	□0 □≤10 □≤50 □>50	
								□清澈 □帶白色 □混濁 □其他	□0 □≤0.5 □≤1 □>1-2	□0 □≤0.5 □≤1 □>1-4	□0 □≤10 □≤50 □>50	
年 月 日 (:)								□清澈 □帶白色 □混濁 □其他	□0 □≤0.5 □≤1 □>1-2	□0 □≤0.5 □≤1 □>1-4	□0 □≤10 □≤50 □>50	
								□清澈 □帶白色 □混濁 □其他	□0 □≤0.5 □≤1 □>1-2	□0 □≤0.5 □≤1 □>1-4	□0 □≤10 □≤50 □>50	
年 月 日 (:)								□清澈 □帶白色 □混濁 □其他	□0 □≤0.5 □≤1 □>1-2	□0 □≤0.5 □≤1 □>1-4	□0 □≤10 □≤50 □>50	
								□清澈 □帶白色 □混濁 □其他	□0 □≤0.5 □≤1 □>1-2	□0 □≤0.5 □≤1 □>1-4	□0 □≤10 □≤50 □>50	
年 月 日 (:)								□清澈 □帶白色 □混濁 □其他	□0 □≤0.5 □≤1 □>1-2	□0 □≤0.5 □≤1 □>1-4	□0 □≤10 □≤50 □>50	
								□清澈 □帶白色 □混濁 □其他	□0 □≤0.5 □≤1 □>1-2	□0 □≤0.5 □≤1 □>1-4	□0 □≤10 □≤50 □>50	
年 月 日 (:)								□清澈 □帶白色 □混濁 □其他	□0 □≤0.5 □≤1 □>1-2	□0 □≤0.5 □≤1 □>1-4	□0 □≤10 □≤50 □>50	
								□清澈 □帶白色 □混濁 □其他	□0 □≤0.5 □≤1 □>1-2	□0 □≤0.5 □≤1 □>1-4	□0 □≤10 □≤50 □>50	
年 月 日 (:)								□清澈 □帶白色 □混濁 □其他	□0 □≤0.5 □≤1 □>1-2	□0 □≤0.5 □≤1 □>1-4	□0 □≤10 □≤50 □>50	
								□清澈 □帶白色 □混濁 □其他	□0 □≤0.5 □≤1 □>1-2	□0 □≤0.5 □≤1 □>1-4	□0 □≤10 □≤50 □>50	
年 月 日 (:)								□清澈 □帶白色 □混濁 □其他	□0 □≤0.5 □≤1 □>1-2	□0 □≤0.5 □≤1 □>1-4	□0 □≤10 □≤50 □>50	
								□清澈 □帶白色 □混濁 □其他	□0 □≤0.5 □≤1 □>1-2	□0 □≤0.5 □≤1 □>1-4	□0 □≤10 □≤50 □>50	

(4)耗材/消耗品管理紀錄表

項目名稱	SFDF-0016						
來貨日期	耗材種類	耗材名稱（耗材代碼）	採購數量	來貨單價(元)	供應商名稱	產品製造日期/批號	備註
年 月 日	□飼料 □設備 □藥物 □其他						
年 月 日	□飼料 □設備 □藥物 □其他						
年 月 日	□飼料 □設備 □藥物 □其他						
年 月 日	□飼料 □設備 □藥物 □其他						
年 月 日	□飼料 □設備 □藥物 □其他						
年 月 日	□飼料 □設備 □藥物 □其他						
年 月 日	□飼料 □設備 □藥物 □其他						
年 月 日	□飼料 □設備 □藥物 □其他						
年 月 日	□飼料 □設備 □藥物 □其他						
年 月 日	□飼料 □設備 □藥物 □其他						
年 月 日	□飼料 □設備 □藥物 □其他						
年 月 日	□飼料 □設備 □藥物 □其他						
年 月 日	□飼料 □設備 □藥物 □其他						
年 月 日	□飼料 □設備 □藥物 □其他						

(5)魚苗成長/銷售紀錄表

項目名稱	SFDF-0016							
日期	苗種名稱	苗種批號	體型大小(cm; kg)	數量(尾)	單價(元)	總價(元)	採購商	備註
年 月 日								
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SKLMP
海洋污染國家重點實驗室